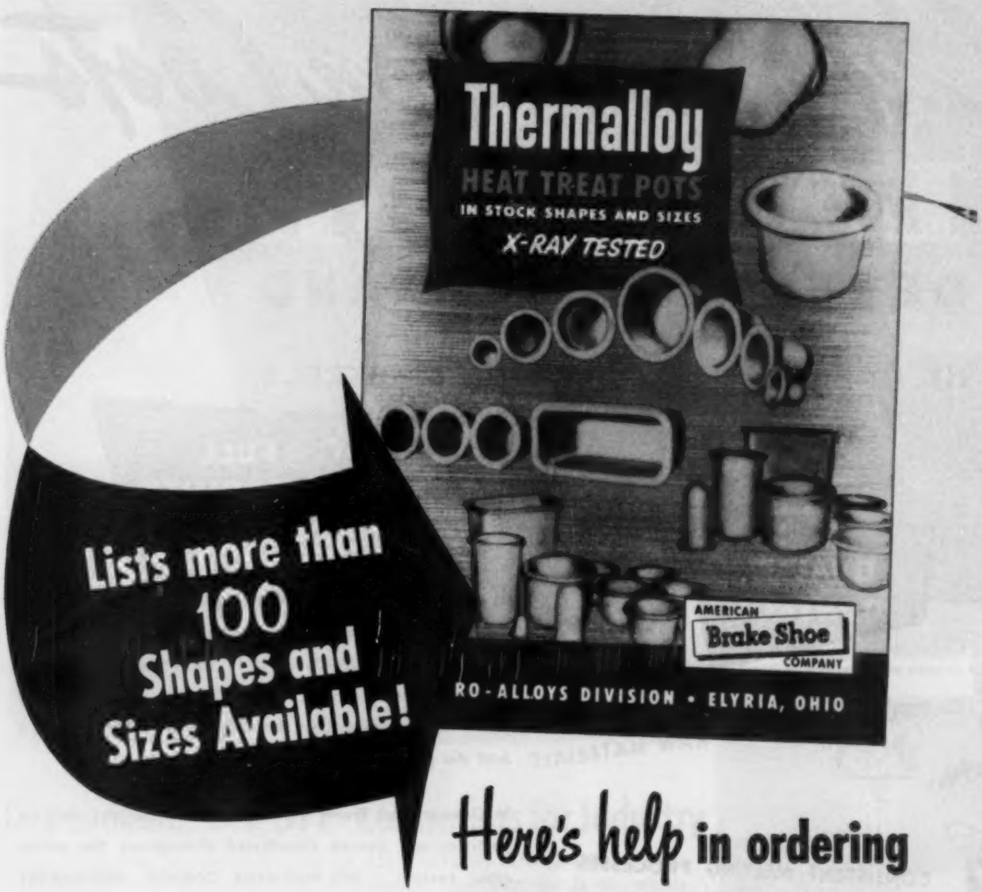


Here's help in ordering HEAT TREAT POTS!

You can save time and pattern costs by ordering Thermalloy Heat Treat Pots in shapes and sizes available for production. This new bulletin lists 118 pattern numbers available—including both round and rectangular pots.

All Electro-Alloys heat treat pots are x-rayed and pressure tested, to insure the soundness necessary for low cost service. Analyses available for cyanide salt and lead service—and for neutral salt service.

Write for Bulletin T-205. Electro-Alloys Division, Dept. 2091, Elyria, Ohio.

*Reg. U. S. Trade Mark

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION

ELYRIA, OHIO

Cut Production Costs

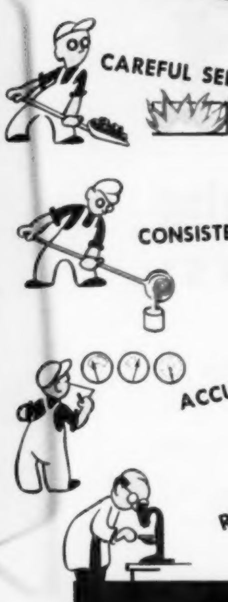
LATROBE

DESEGATIZED BRAND

HIGH SPEED STEELS
HI CARBON – HI CHROME DIE STEELS

*** FULL UNIFORMITY**

*** QUALITY CONTROL**



CAREFUL SELECTION OF RAW MATERIALS

CONSISTENT MELTING PROCESSES

ACCURATE FINISHING STANDARDS

RIGID INSPECTION PRACTICES

Latrobe's Desegatized Brand high speed steels and hi carbon - hi chrome die steels will help you cut production costs. Rigorous quality control - from material selection through product inspection - plus the full uniformity found in all Desegatized Brand steels assures better tool and die performance and longer production life.

In Desegatized Brand steels, the all-important carbide particles are evenly distributed throughout the entire cross section - NO HARMFUL CARBIDE SEGREGATES ARE PRESENT! This results in extra toughness and strength . . . cracks, checks and warpage in heat treatment are radically minimized . . . superior machining and grinding abilities result.

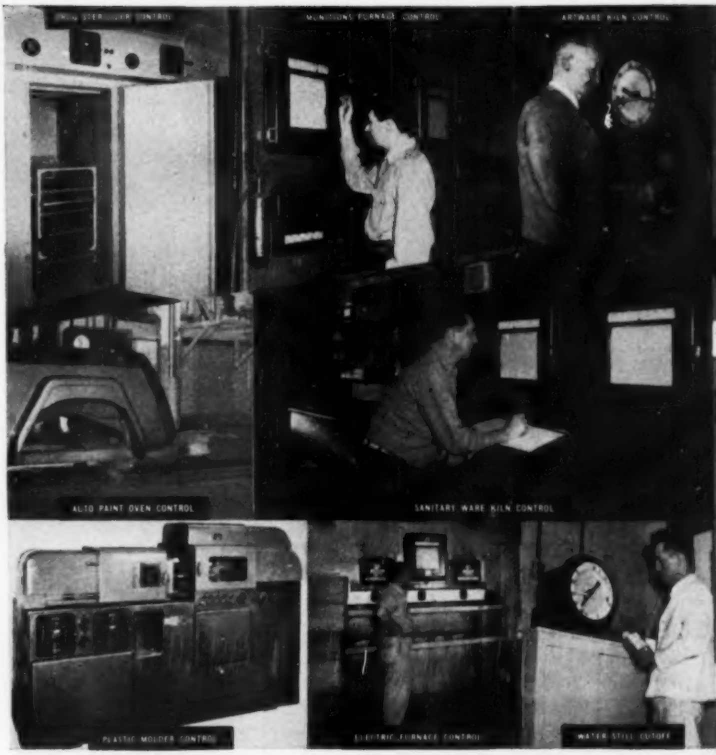
Specify Latrobe's Desegatized Brand tool and die steels for better performance and resulting lower production costs.

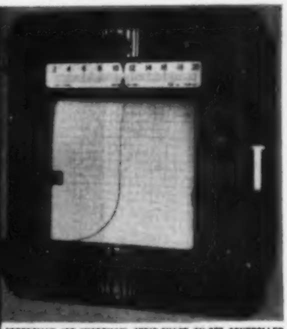
Send for booklet "WHY DESEGATIZED" showing superiority of Desegatized Brand steels over average standard process steels.

LATROBE ELECTRIC STEEL COMPANY
LATROBE, PENNSYLVANIA

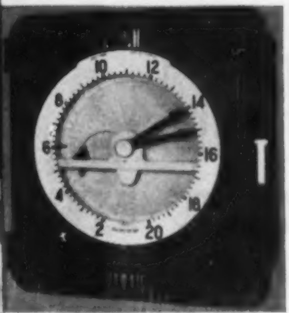
Branch Offices and Warehouses located in: DETROIT, TOLEDO, DAYTON, PITTSBURGH, LOS ANGELES, PHILADELPHIA, CHICAGO, CLEVELAND, NEW YORK, BOSTON, SEATTLE, MILWAUKEE, HARTFORD, ST. LOUIS, BUFFALO.

Sales Agents: DALLAS, HOUSTON, WICHITA, DENVER, BIRMINGHAM.

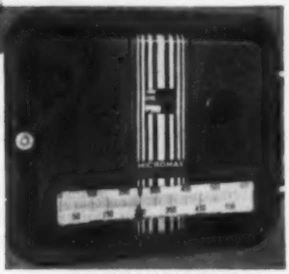




SPEEDOMAX (OR MICROMAX) STRIP-CHART ON-OFF CONTROLLER



SPEEDOMAX ROUND-CHART ON-OFF CONTROLLER



MICROMAX MODEL C ON-OFF CONTROLLER

ELECTROMAX ON-OFF CONTROLLER

Dependable "ON-OFF" Controllers for Industry

THE kind of control instrument which industry calls on-off or 2-position is not only the oldest form of automatic regulator, but is one which many manufacturers still use, instead of more advanced types, for simple requirements. Usually, the instrument merely closes the valve when temperature reaches the control point, and opens valve again when temperature falls below point. The question of whether such on-off action is best for the given case can of course be settled by using the instrument with the best, most useful features. Here are some which L&N On-Off Controllers offer:

1. Instruments may be Recording Controllers with either strip-chart or round-chart, or Controllers with no charts at all.
2. Instruments can operate at high or moderate speed; can be located regardless of machine vibration, building tremors or distance from process.
3. Controls are outstandingly dependable because they "balance" temperature against a standard. Intermediate bearings and springs cannot increase, decrease or otherwise influence accuracy or sensitivity.
4. Low maintenance assured by machine-like design and construction.
5. More than 1000 standard ranges. Specials are available, but seldom needed.

Tell us your problem and we will send further information. Write either to our nearest office or to 4927 Stenton Avenue, Philadelphia 44, Pa.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

THESE instruments are fully automatic; need no standardizing; are ideal even for hard-to-get-at or difficult locations.

Jrl. Ad ND4-33(3)

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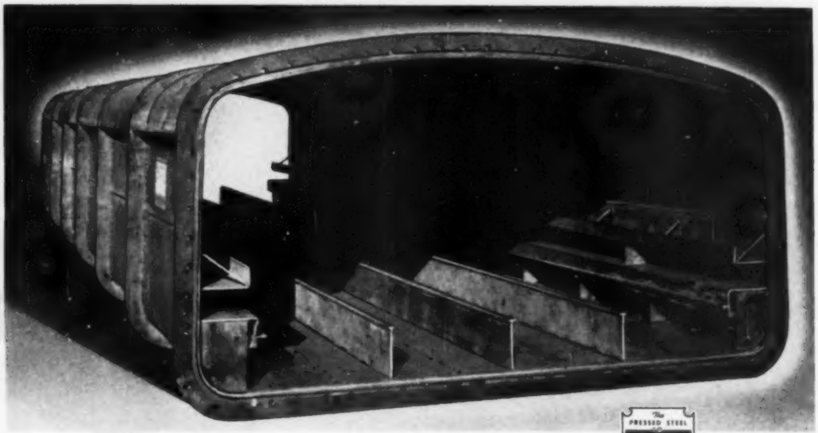
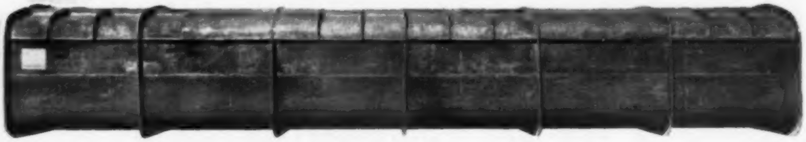


PSC "LIGHT-WEIGHT" MUFFLES
CUT HEAT-HOUR COSTS
of controlled-atmosphere annealing



Above is a 40-foot muffle, made in two sections for ease of installation in a pusher-type annealing furnace of a leading brass manufacturer. 6 feet wide and 3 feet high, the sections were bolted together at the flanges. The unit was entirely fabricated of 1/4" alloy to give the economies of PSC "light-weight" construction. Although a set operating study has not been made, our customer reports a substantial saving in fuel and heating time.

The above muffle was fabricated of 12-14 alloy, for low-temperature gas-fired annealing (up to 1250°). PSC muffles are furnished in any desired alloy, for temperatures to 2200°; in any size and for any type furnace.

In cases of special furnaces, limited space and other situations, the design of a muffle becomes a prime factor in successful operation of the furnace. To assure you uniform controlled heating as well as strength and long life, we invite you to take advantage of our over 20 years experience in designing and fabricating a complete line of heat-treating carriers. Write as to your needs or for address of your nearest PSC representative.

PSC EQUIPMENT IS "ALLOY RIGHT"

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆

The part that cost 34% less when made from TIMKEN® seamless tubing

HERE ARE THE COST FIGURES:

	BAR STOCK	TIMKEN TUBING
Cost of material per 1000 pieces	$68.16	$49.25
Material savings with tubing—$18.91		
Number of pieces produced per hour on six-spindle 2⅜" capacity automatic screw machine	163	300
Machining cost per 1000 pieces (estimated machine operating cost per hour—$6.50). . .	$39.88	$21.67
Machining savings with tubing—$18.21		

TOTAL SAVINGS WITH TUBING—$37.12, or 34.3%

IF machined from bar stock, the part shown here would cost 10.8¢. But it is costing the manufacturer only 7.09¢—because it's made from Timken® seamless tubing. How was this 34% saving possible? The figures above tell the story.

Timken tubing eliminates drilling because the hole is already there. You usually can start right in with finish boring. There's less stock to machine—less scrap loss. And because of the uniformly fine forged quality of Timken steel, you get a better finished product.

To get the most economical tube size for your job, guaranteed to clean up, use our Tube Engineering Service. With the tube we specify, there's no excessive stock, yet you're sure of enough metal to fill out your dimensions. It's *guaranteed*. Write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing.

321 STAINLESS

An Assured Supply Lower Cost Technical DATA*

*The assurance of a continuous supply of Titanium to make stabilized austenitic chromium nickel steel...plus the economic advantage of the lower price of type 321 has focused increasing attention on its other outstanding features. Among these are excellent high temperature properties, thermal shock resistance and ease of drawing and forming.

In the "as-welded" state, as normally used, 321 shows a high order of corrosion resistance in a variety of corrosive media. It is being used effectively in many installations with type 347 weld rods used in welding.

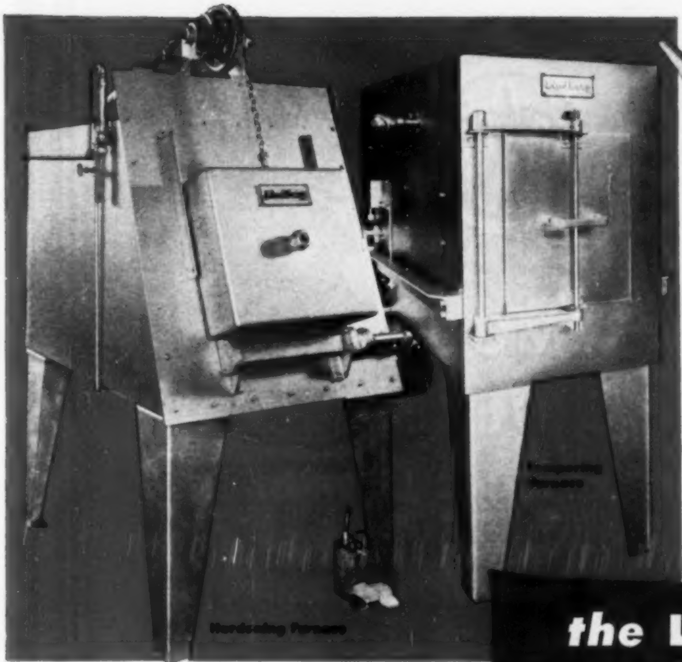
* In developing the Low Carbon Ferro Titanium alloys used in making 321 stainless, TAM has acquired much worthwhile technical data. Therefore, although we do not supply steel, we can supply you with information of value. Write our New York City Office.

TAM PRODUCTS
Registered U.S. Pat. Off.

*TAM is a registered trademark.

TITANIUM ALLOY MFG. DIVISION
NATIONAL LEAD COMPANY

Executive and Sales Office: 111 BROADWAY, NEW YORK CITY · General Offices, Works, and Research Laboratories: NIAGARA FALLS, N. Y.



BASIC FOR EVERY TOOLROOM

the LINDBERG TOOLROOM TEAM

When production depends on tools and dies, tools and dies depend on the LINDBERG TOOLROOM TEAM—a basic requirement in every toolroom—a must where you want the ultimate in tools and dies which will keep your production rate up and your machinery running with a minimum of tool and die failure. The LINDBERG TOOLROOM TEAM gives you the precision heat treating which your precision tools and dies need for lasting performance.

LINDBERG HARDENING FURNACE—eliminates finishing due to scale and decarb with simple accurate atmosphere control.

LINDBERG TEMPERING FURNACE—allows you to obtain the exact "Rockwell Hardness" required for each specific tool or die.

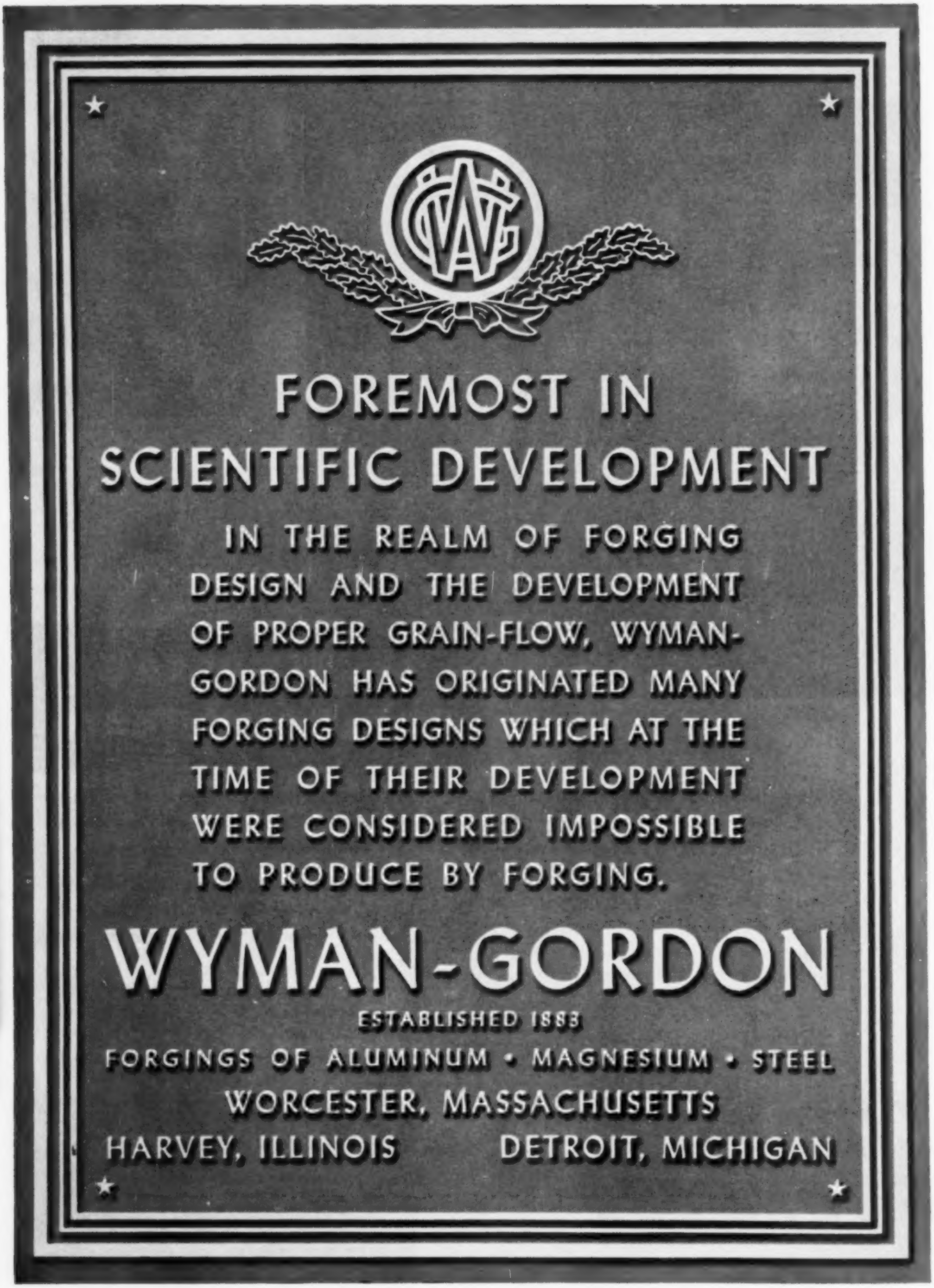
For tools and dies requiring high speed tool steel—investigate the Lindberg "L" Type combination preheat—high heat Furnace.

LINDBERG FURNACES

LINDBERG ENGINEERING COMPANY W. Hubbard Street, Chicago 12, Illinois

***Specify* LINDBERG**

for any heat treating or melting need!


FOREMOST IN
SCIENTIFIC DEVELOPMENT
IN THE REALM OF FORGING DESIGN AND THE DEVELOPMENT OF PROPER GRAIN-FLOW, WYMAN-GORDON HAS ORIGINATED MANY FORGING DESIGNS WHICH AT THE TIME OF THEIR DEVELOPMENT WERE CONSIDERED IMPOSSIBLE TO PRODUCE BY FORGING.
WYMAN-GORDON
ESTABLISHED 1883
FORGINGS OF ALUMINUM • MAGNESIUM • STEEL
WORCESTER, MASSACHUSETTS
HARVEY, ILLINOIS
DETROIT, MICHIGAN

HARDEN MOLYBDENUM HIGH SPEED STEEL TOOLS WITHOUT DECARB

Typical installation for hardening high speed tools. Preheat, high heat and quench furnaces. The center unit operating at 2300°F. is equipped with submerged electrodes which [illegible]

Following are but a few leading users of Ajax furnaces:

AC Spark Plug Div.
American Twist Drill Co.
Brown & Sharpe Mfg. Co.
Buick Motor Div.
Chevrolet Motor Div.
Cleveland Twist Drill Co.
Commercial Steel Treating Co.
Henry Disston & Sons Co.
Ford Motor Co.
Frigidaire Div.
General Electric Co.
Gorham Tool Co.
Greenfield Tap & Die Co.
Landis Machine Co.
McCroskey Tool Corp.
Midvale Co.
Morse Twist Drill Co.
Mueller Brass Co.
National Cash Register Co.
National Screw Co.
National Tool Co.
Oliver Iron & Steel Co.
Pipe Machinery Co.
Pratt & Whitney Div.
Republic Steel Co.
Stanley Works
Thompson Products Co.
Threadwell Tap & Die Co.
Union Twist Drill Co.
Wesley Steel Treating Co.
Westinghouse Electric Co.

Tungsten is scarce—and, just as happened during World War II, may become much scarcer. This means wider use of high-speed molybdenum steel tools with their critical hardening problems for which the Ajax Electric Salt Bath supplies far and away the most logical, efficient and economical answer. Actually, it was the inherent characteristics of the salt bath that, to a large extent, made feasible the adoption of molybdenum high-speed steels in place of the tungsten types.

Scaling, decarb, oxidation, pitting and other surface defects are *automatically* avoided. Distortion is reduced to a negligible minimum. Immersion in the bath seals the work from all atmosphere. A protective film of salt protects the tools fully, right up to the instant of quenching.

Heating is amazingly rapid and uniform. Thanks to the exclusive Ajax electrodynamic stirring action, the temperature will not vary more than 5°F. *in any part of the bath.* Because of its faster heating cycles, productive capacity of an Ajax salt bath is two or three times that of other heat treating methods.

In short, the Ajax furnace makes it just as easy and practical to harden molybdenum steels as any other kind—and the equipment works equally well in heat-treating tungsten steels, high carbon—high chromium and all other tool steels.

Be prepared! Ajax Bulletin 123 tells the complete story. Write for your copy today.

More molybdenum high-speed tools are hardened in Ajax Salt Bath furnaces than in any other equipment!

AJAX ELECTRIC COMPANY, INC.

910 Frankford Ave. Philadelphia 23, Pa.

World's largest manufacturer of electric heat treating furnaces exclusively

AJAX ELECTRIC SALT BATH FURNACES

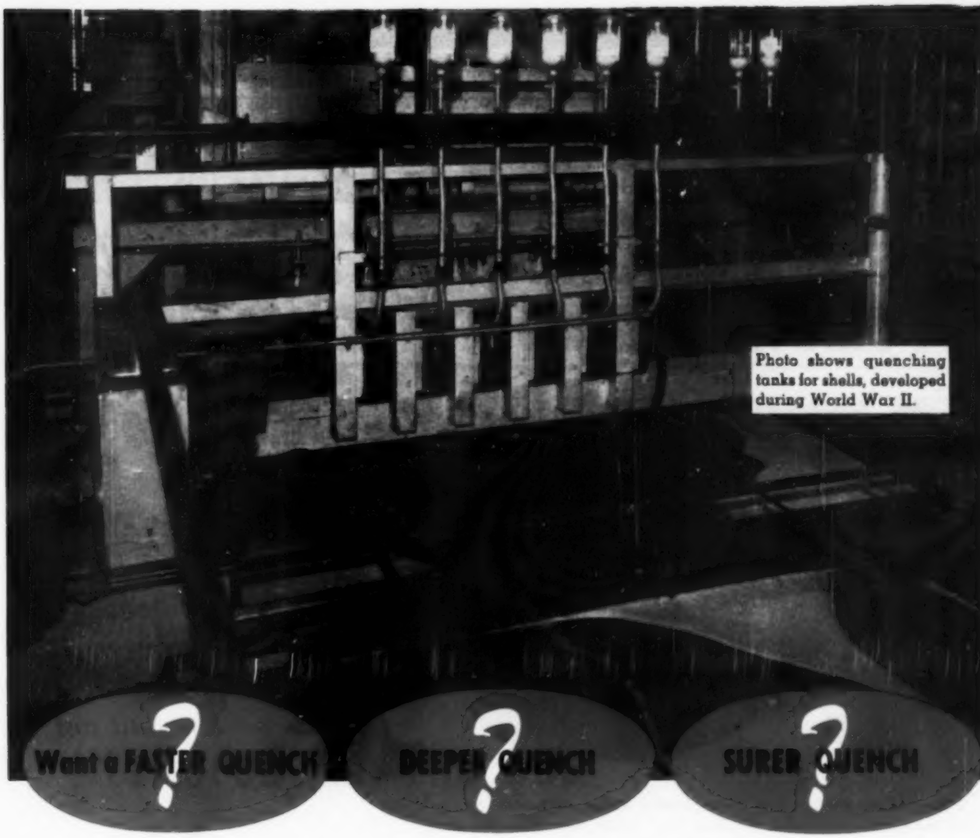


Photo shows quenching tanks for shells, developed during World War II.

...then you need HOUGHTO-QUENCH!

That's the oil that saved the day for so many metalworking plants during the critical shortage of alloying elements in World War II, by giving them a faster quenching speed through the critical zone.

Now it's even faster, assuring maximum hardness even with lean alloy steels—again a necessity.

Houghto-Quench is stable and long-lived. It may well be the answer to your quenching problem. Ask the Houghton man, or write us direct. E. F. Houghton & Co., Philadelphia 33, Pa.

HOT OIL QUENCHING

Now, to avoid distortion, it is possible to use hot oil, at temperatures up to 350° F., without undue thickening or oxidation. Write for folder on Houghton's MAR-TEMP Oil.

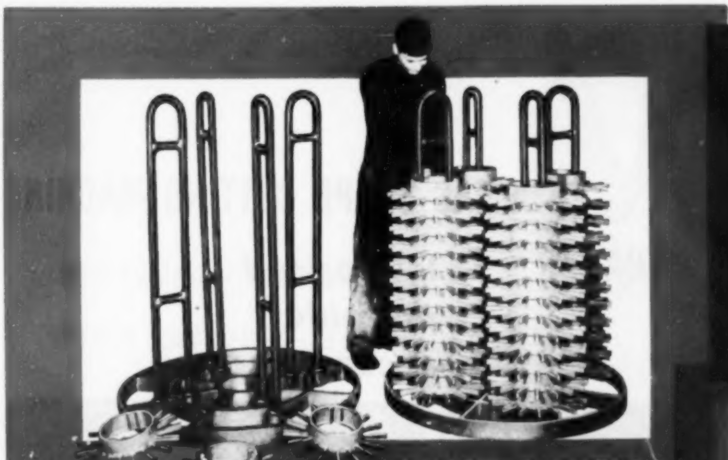
HOUGHTO-QUENCH OIL

. . . a product of

E. F. HOUGHTON & CO.

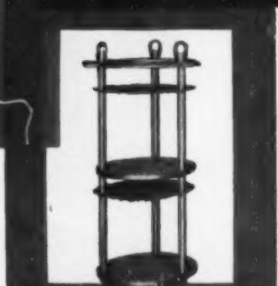
PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service . . .



Four-stack Fixture—40" diameter—58" high

Center-post Fixture — 22" diameter—28" high



Two-level Fixture — 24" diameter—55" high

Furnace Loads Increased with D-H Fixtures "tailored for The Job"

When vertical carburizing furnaces became popular, Driver-Harris made close studies relative to loading capacities, and decided that fixtures specially designed to meet individual requirements would enable live load percentages to be increased, and loads to be more easily handled.

Custom-built equipment pioneered by Driver-Harris proved so successful that for fifteen years this firm has continued to specialize in producing furnace parts and fixtures "tailored for the job." In every instance, load ratio has been improved and load handling facilitated.

Here are a few typical examples picked from hundreds of applications in service today. These fixtures are made of Chromax* and Nichrome*—the high heat and corrosion-resistant alloys that are unsurpassed for heat-treating applications. Components consist of castings, forgings, hot rolled rod, sheet and wire—all produced in Driver-Harris' own plant to meet given requirements.

Such products exemplify the exceptional facilities at the disposal of Driver-Harris for designing and manufacturing equipment of this type. Moreover, since Driver-Harris is both producer and processor of numerous alloys, it is not prejudiced in favor of a particular material or process. Whatever is best suited to achieve peak performance is utilized. To have furnace parts and fixtures designed and produced by Driver-Harris, therefore, means that your specific needs are met in the most efficient manner possible.

Under present conditions, exceptional demand is engaging the resources of the Driver-Harris Company to an unprecedented extent. Nevertheless, we shall be happy to have you consult with us, and shall be glad to serve you to the best of our ability.

Nichrome and Chromax are manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

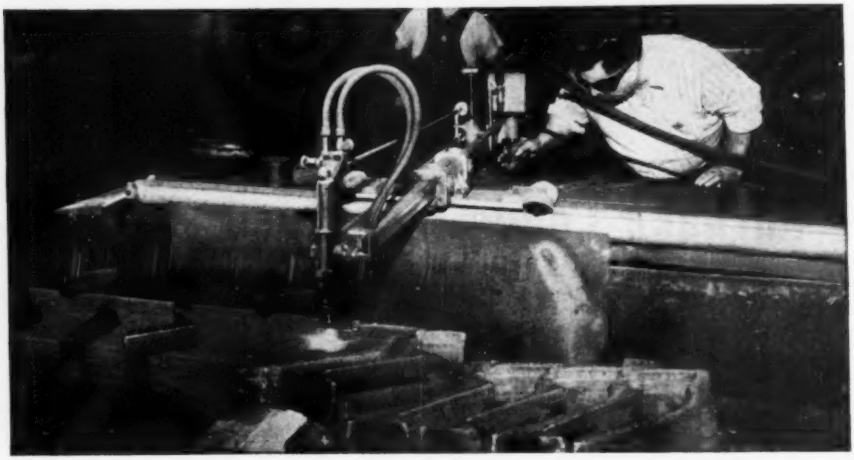
SPECIAL PURPOSE ALLOYS SINCE 1899 D/H TRADE MARK REG. U. S. PAT. OFF.

*T.M. Reg. U. S. Pat. Off.

NOW

A GAS SHAPE CUTTING MACHINE

THAT IS: *1. low-priced*
2. portable
3. accurate



That's a statement that is 100% true! In one shop they found this new machine—the AIRCO No. 3 MONOGRAPH—excellent for shape cutting the 1001 odd jobs that constantly came up!

In fact, they have cut more than 16,000 drop-floor hinges alone—stack cutting them from mild steel plate, as shown above. This one operation saved more than the price of the machine. In addition, they cut hundreds of other parts—body center plate blanks, engine truck roller racks, spring hangers, pipe clamps and many others.

The NEW Airco No. 3 Monograph will handle practically any cutting job—straight line, circle, or bevel, in addition to angles, curves and other ordinary shapes. It can be used stationary or portable, as the occasion demands.

This NEW machine, lowest priced of its type on the market (only $695, including a manual tracing device, torch, tip, tubular rail, hose and carrying case), will cut steel up to 8 inches thick. Its cutting area is 32 inches by 56 inches, and with the addition of sections of 6-foot, 8-inch tubular rail, the length of the cutting area can be extended as desired.

SPECIAL TRIAL OFFER

(Good in Continental U.S.A. Only)

If you would like to try this machine for two weeks in your own shop on your own work, just drop a letter to your nearest Airco office, and they will advise you how this can be arranged . . . or, if you would like a descriptive folder (ADC-660), they will be glad to send you one.

AIRCO **AIR REDUCTION**

AIR REDUCTION SALES COMPANY • AIR REDUCTION MAGNOLIA COMPANY
AIR REDUCTION PACIFIC COMPANY
REPRESENTED INTERNATIONALLY BY AIRCO COMPANY INTERNATIONAL

Divisions of Air Reduction Company, Incorporated

Offices in Principal Cities

Nothing takes the place of Chromel Alumel thermocouples

When you're working with heat between 1000° and 2000° F. and accurate temperature measurement is essential to the results you want to produce, you'll find there is no suitable substitute for Hoskins CHROMEL-ALUMEL thermocouple alloys. They're unconditionally guaranteed to register true temperature—E.M.F. values within very close specified limits. Exceptionally durable . . . so resistant to oxidation that you need not pack the protection tube. Hence, highly responsive to temperature fluctuations. And, in spite of hard use, they maintain their fine degree of accuracy over far longer periods of time than any other known base metal thermocouple materials.

So for positive long-life assurance of accurate temperature measurement, insist that your pyrometers be calibrated for CHROMEL-ALUMEL thermocouples. And important, too . . . be sure you use CHROMEL-ALUMEL *extension* leads instead of so-called "compensating" wires. For, when the couple and the lead are of identical alloy compositions there is no possibility of "cold-end" errors. Our Catalog 59-R contains a complete technical explanation . . . want a copy?

CHROMEL-ALUMEL couples and leads are available through your instrument manufacturer or pyrometer service company . . . ask for them by name!

HOSKINS MANUFACTURING COMPANY

4445 LAWTON AVE. • DETROIT 8, MICHIGAN

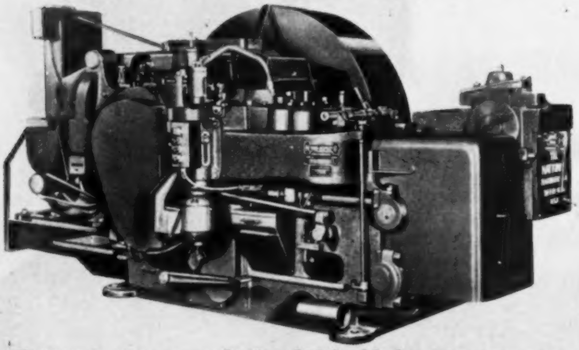
NEW YORK • CLEVELAND • CHICAGO

West Coast Representatives in Seattle, San Francisco, Los Angeles
In Canada: Walker Metal Products, Ltd., Walkerville, Ontario

**the ickel-chromium resistance alloy that first made electrical heating practical*

PROGRESS IN FASTENERS...

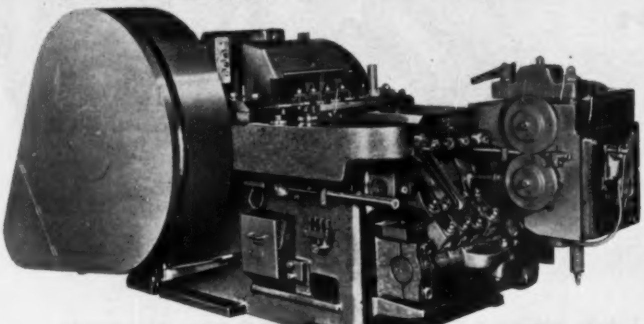
Record-Shattering Million Tons Shipped Last Year!



The American Fastener Industry shipped 1,000,000 tons of fasteners in 1950 . . . more than in any previous year.

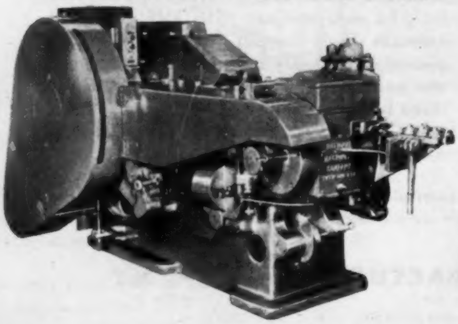
NATIONAL is proud of the part that the methods and machines which it has engineered and developed, have played in this accomplishment.

BOLTMAKERS are producing finished bolts, cap screws, and a variety of other work, by combining extrusion, upsetting, trimming, pointing, and thread rolling—all on one machine!



NATIONAL NUT FORMERS incorporate the National-developed method of cold-forging nut blanks. These machines are recognized for their ability to produce blanks of outstanding quality at high efficiencies.

NATIONAL HIGH SPEED PRECISION NUT TAPPERS automatically tap nuts to close fits. Operating advantages include new high speeds, unexcelled accuracy, long tap life, quick tap change, and built-in safety devices.



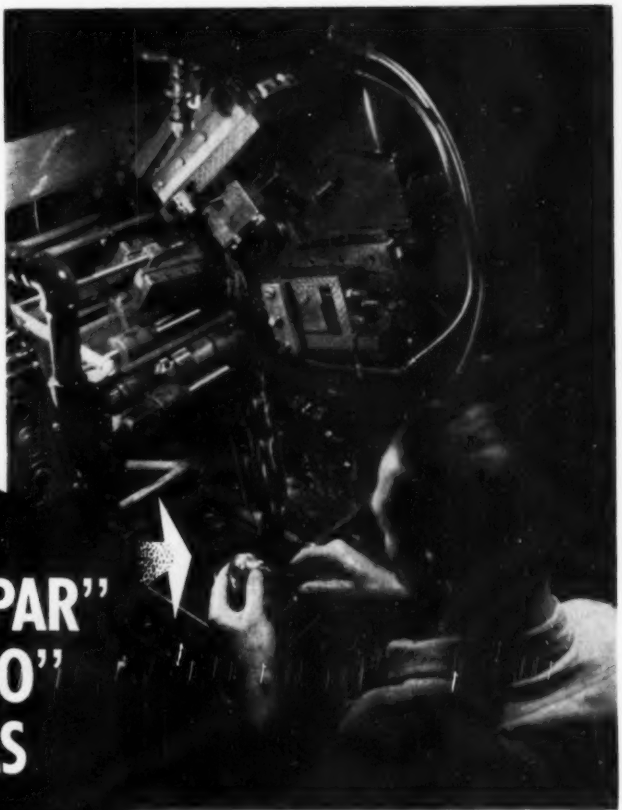
Rugged, dependable NATIONAL COLD HEADERS are producing a wide variety of work to dial-indicator exactness at high speeds. Machines feature ease of set-up and low-maintenance cost.

NATIONAL
MACHINERY COMPANY
TIFFIN, OHIO.

DESIGNERS AND BUILDERS OF MODERN FORGING MACHINES—MAXIPRESSES—COLD HEADERS—AND BOLT, NUT, RIVET, AND WIRE NAIL MACHINERY

Hartford **Detroit** **Chicago**


Finer
STRIP STEELS
FOR YOU IN 1951!



Up to 35% greater production, much longer tool life

with GULF "LASUPAR" and "ELECTRO" CUTTING OILS

These new improved Gulf sulphurized cutting oils contain sulphur combined by a special Gulf Process so that it is extremely active over the entire range of a cutting operation. That's the important reason why users are able to step up feeds and speeds on tough machining jobs. They report production increases of as much as 35% after switching from conventional oils of this type.

Gulf Lasupar and Electro Cutting Oils provide excellent protection for the tool at elevated production rates —help reduce built-up edge, prevent chip welding, prolong tool life.

Because Gulf Electro Cutting Oil contains a larger percentage of this extremely active sulphur ingredient, it is recommended for the toughest machining jobs, where production and tool life are a problem.

Gulf Lasupar Cutting Oil also contains stable sulphurized fatty oil, effective in producing the fine finishes for which this quality cutting oil is so well known.

Operators everywhere welcome the new Gulf Lasupar and Electro Cutting Oils—because they get all these production advantages without the disagreeable odor ordinarily associated with sulphurized cutting oils.

Call in a Gulf Lubrication Engineer today and arrange to use these outstanding oils in your shop. Or send the coupon below for additional information.

FIFTY YEARS OF SERVICE
1901 GULF 1951
PETROLEUM AND ITS PRODUCTS

Gulf Oil Corporation · Gulf Refining Company MP
3-SZ Gulf Building, Pittsburgh 30, Pa.

Please send me, without obligation, a copy of each of your new pamphlets "Gulf Lasupar Cutting Oil," "Gulf Electro Cutting Oil."

Name ....
Company ....
Title ....
Address ....

Republic Metallurgical Service

Reduces SCRAP LOSS, *Improves* MACHINABILITY for leading aircraft propeller manufacturer

To achieve in a hollow steel structure the complex curvatures and delicate balance required in a propeller blade, many unusual forming and welding operations are required. This is particularly true in fabricating alloy steel plate into finished blades for such sky giants as the B-36 and B-29. Investments in machining time are high.

Wih the object of improving machinability, lengthening tool life and minimizing scrap losses, metallurgists of the Propeller Division, Curtiss-Wright Corporation, called in Republic Steel metallurgists. Together they attacked the problem of modifying plate hardness and structure.

A slightly revised chemistry was agreed upon, and a commercially practical annealing cycle was developed. Results were immediate: plate hardness and structure were brought within acceptable limits. This, in turn, gave improved formability, machinability and tool life. Scrap loss in preliminary machining and forming operations was practically eliminated.

Perhaps you have a question concerning your own use of alloy steels. Republic metallurgical, machining and technical staffs will be glad to go to work on it in cooperation with your own personnel. Their service is completely confidential, of course, and carries no obligation. Just write:

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N.Y.

LAB MILL FIELD
3-DIMENSION Metallurgical Service

...combines the extensive experience and coordinated abilities of Republic's *Field, Mill* and *Laboratory* Metallurgists with the knowledge and skills of your own engineers. It has helped guide users of Alloy Steels in countless industries to the correct steel and its most efficient usage. IT CAN DO THE SAME FOR YOU.

Republic ALLOY STEELS

REPUBLIC STEEL

Other Republic Products include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

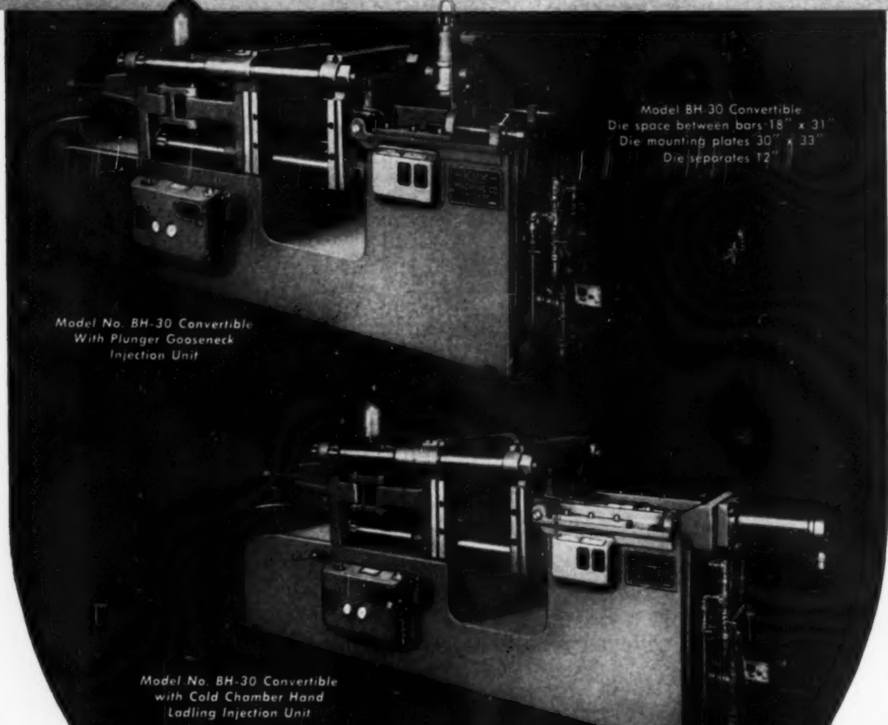
CONVERSION FROM ZINC TO ALUMINUM DIE CASTING

in less than an hour on

KUX CONVERTIBLE MACHINES

In less than an hour's time, Kux hydraulic machines can be adjusted for die casting zinc alloys using a plunger gooseneck metal injection unit or for die casting aluminum brass or magnesium alloys using a cold chamber hand ladling injection unit.

This change over is a simple easy operation on any of the Kux machines from Model BH-18 to Model BH-30 which are available as convertibles. The removal of a few mounting screws and pins and the attachment of either injection unit, both completely self-contained, rapidly readies a machine for production. Only on Kux Die Casting equipment can you find so many superior design features that offer such a multiplicity of usage for each machine. Write now for illustrated catalog.



Model BH-30 Convertible
Die space between bars 18" x 31"
Die mounting plates 30" x 33"
Die separates 12"

Model No. BH-30 Convertible
With Plunger Gooseneck
Injection Unit

Model No. BH-30 Convertible
with Cold Chamber Hand
Ladling Injection Unit

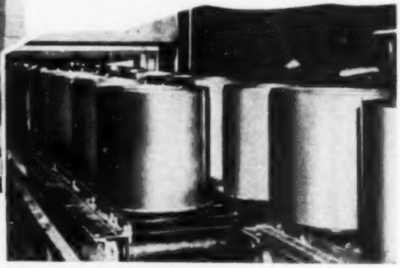
KUX MACHINE COMPANY

3940 W. HARRISON STREET • CHICAGO 24, ILLINOIS


GALVANITE
MAKES BETTER PRODUCTS FOR THE
AUTOMOTIVE INDUSTRY
Almost every automobile operating on the roads today has parts made of Galvanite*. It may be the door lock, window channels, speedometer cable, hose clamps, exhaust pipe, hub caps, kick plates or the shim stock used to make the parts fit tighter. But whatever it is that is made of Galvanite* it is sure to be the best part available at any cost.
For Galvanite* is the tremendously popular zinc coated steel that fabricates like ordinary cold rolled steel yet resists rust and corrosion for years. What's more Galvanite* has a "matte" surface that grips paint in an everlasting bond.
The Galvanite* zinc coat is put on to stay. It is accurate and uniform—tough and pliant. It will not flake or peel, or clog dies.
Brochure giving test data, etc. upon request.
*Manufactured exclusively by the Sharon Steel Corporation under patented process.
SHARON STEEL CORPORATION
Sharon, Pennsylvania
SHARONSTEEL

◀ A battery of Inconel conveyor rolls in a brass strip annealing furnace, Scovill Mfg. Co., Waterbury, Conn. The furnace was fabricated by SURFACE COMBUSTION CORP., Toledo, Ohio.

Input end of brass annealing furnace showing coiled brass strip resting on Inconel furnace pans at Scovill Mfg. Co., Waterbury, Conn. These circular pans were fabricated by THE PRESSED STEEL CO., Wilkes-Barre, Pa. ▼



MODERN furnace equipment in one of world's most MODERN brass mills

Completed in 1949, the new Continuous Strip Mill of Scovill Manufacturing Co., at Waterbury, Conn., is rated as one of the most modern completely integrated brass mills in the world. From the giant continuous slab-casting machinery at one end, to the tractor loaders a quarter of a mile away at the other – every unit operation has been mechanized to the highest degree.

In planning the mill, considerable thought was given to minimizing future maintenance costs. Scovill knew that one source of serious upkeep could be annealing furnace equipment.

So, on the advice of Surface Combustion Corp., and The Pressed Steel Co., annealing furnace pans were made of a metal with a proved record of long life in high-temperature applications . . . INCONEL®. Capable of withstanding temperatures of up to 2000°F., INCONEL promised to give Scovill the long, trouble-free service they wanted.

The conveyor rolls were fabricated from extruded seamless INCONEL tubing. The finished roll dimensions are: 7 in. O.D. with 7/16 in. wall. Effective working width, including end guide collars, is 5 ft. 2 in. The rollers extend through the furnace side walls and are supported by anti-friction, self-aligning bearings.

If you would like to know how – like Scovill – many of the nation's busiest furnace operators are using INCONEL to beat high maintenance costs, write for: *"Keep Operating Costs Down When Temperatures Go Up."*

Remember, too . . . Inco's Technical Service Department is always ready to help you solve high-temperature metal problems.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

EMBLEM OF SERVICE INCO TRADE MARK

INCONEL . . . for long life at high temperatures

Engineering Digest of New Products

CORE-BAKING OVEN: The new Gordon-Campbell core-baking oven has a heavily insulated chamber 10 in. wide, 12 in. high, 18 in. deep, designed for maximum temperature of 550° F. with sensitive, automatic,

thermostatic control. A special double type air-diffusing system is employed to insure a large volume of air to enter the oven with an equal amount of air intake at both the front and back of the chamber. In this way with a minimum of three to four air changes per minute, convected heat is used to best advantage for drying and baking, rapidly eliminating the gases and moisture.

For further information circle No. 89 on literature request card on p. 200B

SERRATING TOOL: National Carbon Division, Union Carbide and Carbon Corp., now has available an improved hand serrating tool for use with Karbate brand impervious graphite pipe. The tool is simple, rugged and easy to use, assuring a tight, workmanlike joint in a minimum of time. It provides an advantage over other types of piping since it facilitates quick assembly of Karbate pipe on the job site. Pipe sizes from 1 to 6 in. inclusive may be serrated.

For further information circle No. 90 on literature request card on p. 200B

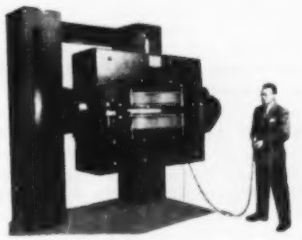
CHIP REMOVAL: The Magnus Aja-Dip chip-removing machine, a product of the Magnus Chemical Co., Inc., is proving a time and money saver in plants where the removal of metal chips and light oil from machined parts has always been a problem. Because the work, as a rule, consists of small units that are more easily handled in tote boxes or baskets in quantity, the removal of the chips from the mass of parts is not easy or anywhere near complete when spray cleaning machines or degreasers are used. In the Magnus machine the batches of parts are vigorously agitated up and down through the cleaning solution 54 times a minute. At each up and down stroke the solution is put in turbulent motion. As the solution rushes back and forth against and through the parts, it scrubs the parts and removes metal chips, oil and dirt even down in the center of the load. The chip-removing job is fully automatic, requiring only manual loading and unloading of the machine—a one-man operation. Magnus chip-removing machines are available in several sizes, handling from 75 to 10,000 pounds of parts per batch.

For further information circle No. 91 on literature request card on p. 200B

PLATE-EDGE PREPARATION: Air Reduction Sales Co. has announced the availability of a new plate-edge preparation device, designed to increase production and insure clean-cut, accurate preparation of plate edges. Its ability to cut a single or double bevel accurately, with or without a land, recommends it especially. It may be mounted on any gas cutting machine equipped with a 3-in. square torch bar. Torches may be individually positioned vertically or laterally without changing the bevel angle. Fuel and preheat pressures are initially set with individual torch valves, and once set, the master valve controls turning-on and shutting-off gas supply without disturbing settings of the individual torch valves.

For further information circle No. 92 on literature request card on p. 200B

BETATRON: The Allis-Chalmers 22-million-volt Betatron, distributed by the Picker X-Ray Corp., is the newest and most efficient tool for production radiography of large heavy-metal castings. X-Rays from the Betatron



will penetrate 20 in. of steel in 10 min. (4 in. of steel in a matter of seconds). Because of its wide latitude (up to 6 in.), fewer radiographs need to be taken. In addition, no time-consuming blocking materials are used. The detail is so excellent that a $\frac{1}{32}$-in. crack is revealed in steel sections ranging from 2 to 12 in. thickness. A $\frac{1}{16}$-in. crack can easily be seen in steel sections 20 in. thick.

For further information circle No. 93 on literature request card on p. 200B

HOT-COLD TEST STAND: Latest addition to the line of testing equipment built by Electro Mechanical Devices is the hot-cold test stand, which will produce any temperature between −70 and +230° F. Designed for testing small aircraft parts, the test stand has a deep well which can accommodate parts measuring up to 6 x 6 x 8 in. The item to be tested is simply placed in the deep well and the thermal selector set at the desired temperature. The deep well is then chilled or heated to the selected temperature. To accommodate testing of small parts which are mounted on larger assemblies and cannot be placed in the deep well, the thermal fluid can be circulated in a closed system a short distance from the test stand in insulated lines.

For further information circle No. 94 on literature request card on p. 200B

Engineering Digest of New Products

MAGNESIUM SAFETY TONGS: Safety tongs of new design and construction have recently been introduced by Magline, Inc., manufacturer of magnesium products for industry. Cast from magnesium alloy, the tongs are designed to crush, if caught within the die opening, without inflicting any damage to the die itself. The tongs are the result of many requests for a unit which would combine lightness, strength and rigidity. They permit easy one-hand operation and clear the way for higher production speeds, while actually reducing operator fatigue. The medium-duty tongs weigh only 6 oz.
For further information circle No. 95 on literature request card on p. 200B

ARGON ARC WELDING: A new hand torch and automatic wire drive unit for argon metal-arc welding has been announced by The Linde Air Products Co. Faster welding can be performed than has ever been possible with hand welding equipment. The consumable electrode serves as the filler metal. Welding rod is fed from

a coil into an argon-protected atmosphere at a steady predetermined rate. The unit consists of the Linde FSH-4 Argon Metal Arc Hand-Welding Torch and the FSM-2 Rod Feed Unit. Hand-welding can be applied on butt, lap, fillet, edge, and corner joints in the overhead and vertical, as well as in the horizontal and flat positions. Argon arc welding has been performed on metal thicknesses from 1/16 to ¾ in. in aluminum and copper alloys, stainless steel, and similar metals. For heavy plate, the multi-pass technique makes possible the welding of any thickness.
For further information circle No. 96 on literature request card on p. 200B

NEW IRIDITE FINISH: A new low-cost Iridite treatment for bright-type finishing of zinc plate in automatic plating machinery has been announced by Allied Research Products, Inc. Like all Iridite finishes, this new compound produces a protective chromate film on the surface of the treated parts. However, its most important advantage is the fact that the protective film can be produced on zinc-plated coatings of less than 0.0001 in. thickness. Thus, the use of new material will enable manufacturers of zinc-plated products to stretch available zinc supplies further. Cost of application per square foot ranges from as low as 3/100¢ for strip-mill plating operations to only 1/10¢ on piece parts in automatic plating machines. The coating itself is bluish bright or yellow iridescent, depending on the user's choice of operating conditions. Corrosion resistance varies upward with the intensity of the iridescence. This new Iridite can be applied from an immersion time that may vary from 20 sec. up to more than a minute. No bleaching operation is required.
For further information circle No. 97 on literature request card on p. 200B

ARC WELDERS: A new series of industrial a-c. arc welders has been announced by Marquette Manufacturing Co. Available in three sizes — 200, 300, and 400-amp. capacities — they are designed for heavy-duty production welding. One of the key construction features is the use of Hipersil transformer cores, which provide greater flux-carrying capacity, reducing power consumption and operating costs.
For further information circle No. 98 on literature request card on p. 200B

New Products

INKLESS STRAIN RECORDER: A new recording SR-4 strain amplifier which reproduces both static and rapidly changing strains, forces, fluid pressures, displacements, vibrations, acceleration, on a strip chart with rectangular coordinates, is announced by the Testing Equipment Dept. of The Baldwin Locomotive Works. It is known as the Baldwin-Sanborn recorder. The instrument is a direct-writing, inkless, vacuum-tube voltmeter consisting of *(a)* an a-c. strain gage amplifier of the conventional modulated carrier type in which the bridge is excited by a built-in oscillator, *(b)* a D'Arsonval moving-coil recording galvanometer in which a current of 10 milliamp. produces a writing arm torque of 200,000 dyne-cm. and 1 cm. deflection, and *(c)* a paper drive mechanism.

The writing arm has a heated stylus which wipes across heat-sensitive record paper as it is pulled over a sharp, straight edge by the paper drive mechanism, thus producing a black line on a white background. Standard paper speed is 25 mm. per sec. When the SR-4 resistance wire strain gage is used, assuming one active gage having a gage factor of 2, the sensitivity is about 50 micro-in. per in. per cm. deflection. Expressed another way, if the resistance of one arm of the bridge changes by one part in 10,000, the deflection of the writing arm will be 1 cm.

For further information circle No. 99 on literature request card on p. 200B

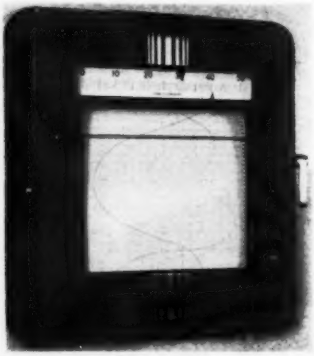
DOUBLE DRUM MAGNET: Dings Magnetic Separator Co. has announced the development of an Alnico double-drum magnetic separator, for the automatic separation of magnetic and nonmagnetic products. This unit is well suited for processing nonferrous chips and fine borings containing less than 10% iron contamination. Nonmagnetic material flows over the drum shell in a normal trajectory. Magnetics are held fast to the surface of the shell for one half revolution until they are carried to a point beyond the magnetic field, to be separately discharged.

The complete unit is available in nine different sizes covering most applications. A 25-in. unit, for example, has a capacity of 2000 to 4000 lb. per hr., depending on the nature of the scrap.

For further information circle No. 100 on literature request card on p. 200B

Engineering Digest of New Products

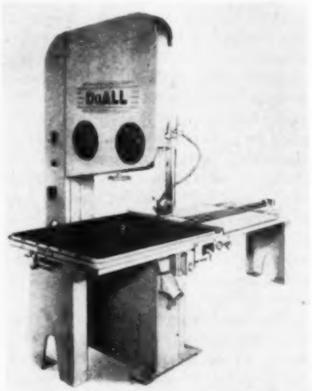
TWO-PEN RECORDER: The new two-pen Speedomax electronic recorder announced by Leeds & Northrup Co. records two functions simultaneously against time. The in-



strument saves tedious compilation and point-by-point plotting of data. Since both functions are drawn as continuous curves on the chart, users can follow swiftly changing variables with ease. Two separate electronically amplified measuring circuits, two balancing motors, and two recording pens are all housed in one standard Speedomax case. Circuits can be supplied to work with thermocouples, Thermohms, strain gages, tachometers, thermal converters, pH cells, or most other types of primary elements. The instrument can operate controls or alarms. Speed of response for full-scale pen movement is 3, 2 or 1 sec., as specified. Chart speed — the Y or time axis — can be selected in the range of 1 to 1800 in. per hr. To aid in identification, the instrument draws one curve in red ink, the other in black.

For further information circle No. 101 on literature request card on p. 200B

BANDSAWING MACHINE: The DoAll Co. announces a powerful new bandsawing machine HP-36 Hydro-Feed. Throat capacity is 36 in., work height from 15½ in. up. The machine uses standard saw bands up to 1 in. width. The HP-36 uses a 10-hp. drive motor. It has a three-speed transmission and variable drive that gives a tool speed range of 40 to 10,000 ft. per min. The hydraulic table will



support workpieces weighing a ton or more. The table slides on 28 rollers distributed over a 36 x 87-in. bed. The in-feed rate is controllable up to 18 ft. per min. with quick return. The HP-36 is designed for heavy-duty precision sawing. It will cut thick sections of any ferrous or nonferrous materials that can be machined with standard carbon steel saw bands. In addition it will friction-saw tough ferrous alloys such as stainless steels up to ½ in. thick several times faster than conventional sawing.

For further information circle No. 102 on literature request card on p. 200B

DIE-CASTING MACHINE: The A. B. C. Die Casting Machine Co. has announced an air-operated zinc die-casting machine with completely automatic cycling and adjustable timing dwell on the opening and closing of the toggle and injection of the molten metal. The machine will produce castings up to 1 lb. utilizing die blocks from 1½ in. thickness by 8 x 10 in. with an allowable increase in die thickness up to 3 in. for each half. The machine is equipped with a 200-lb. pot and is capable of a free cycling speed beyond 1000 shots per hr. It was designed primarily for economical single-cavity dies in view of its speed in production.

For further information circle No. 103 on literature request card on p. 200B

104. Alloy Annealing Slide Chart

Annealing data for the principal analys alloy steels is contained in a convenient chart. On one side is listed data for prod spheroidal structures in 40 alloy types by conventional and isothermal annealing proc The reverse side carries data for producing lan structures, also broken down by conventiona isothermal processes. *Republic Steel Corp.*

105. Alloys

New catalog, "Electromet Ferro-Alloys Metals", lists over 50 metals and alloys describes unique technical service offered t metal industries. *Electro Metallurgical Div.*

106. Alloys, Fabricated

Catalog available showing cost-cutting cated heat treating equipment for higher pay and better quality. *Rolock, Inc.*

107. Alloys, Nickel

New technical bulletin T-6 discusses resis of nickel and its alloys to corrosion by c alkalies. *International Nickel Co.*

108. Aluminum Tubes and Shapes

New price list available on aluminum tube extruded aluminum shapes, rods and bars. *Copper and Brass, Inc.*

109. Belts, Metal

Bulletin 47P illustrates and describes plete line of wire belts for industry. *Ash Brothers, Inc.*

110. Bimetal Elements

64-page catalog written especially to hel design and product engineer select the type size of thermostatic bimetal element best s to his temperature-responsive device. *W, Chace Co.*

111. Brazing Alloys

Standard pricing schedule and torch br instructions for silver brazing alloys liste 4-page leaflet. *American Platinum Works.*

112. Carbon and Sulphur Analysis

Descriptive literature available on carbon sulphur determinators for economical analysis speed and accuracy. *Harry W. Dietert Co.*

113. Castings, Alloy

New reference chart gives detailed inform on analyses, properties and applications with parative designations for stainless, corrosion heat-resistant alloy castings. *Cooper Foundry Co.*

114. Cleaners

New folder describes series of emulsion cle designed to remove both oil-soluble and w soluble soils from any metal or alloy, wit attacking the base metal or paint finishes. *E Corp.*

115. Coatings, Metal

Explanations of high-vacuum evaporatio metals and other solids set forth in detail in 12-page booklet, "Vaporized Metal-Coating High Vacuum". *Distillation Products, Inc.*

116. Control Devices

New 64-page catalog 8303 illustrates over different industrial control devices for tem ture, flow, pressure, liquid level, and humi *Brown Instrument Div.*

117. Control Instrument

Direct-reading spectrometer described in bu 34 is calibrated and adjusted to the parti analytical need of each user. Analysis of as r as 12 elements read directly and simultane from clock dials. *Baird Associates, Inc.*

118. Cutting Oils

Special Gulf process for providing greater sul activity over the entire range of cutting opera described in new pamphlet "Gulf Lasupar Cu Oil". *Gulf Oil Corp.*

119. Electrodes

New 12-page booklet, "The ABC's of We High Tensile Steels", guides buyers and use low-alloy, low-hydrogen electrodes. *Arcos*

120. Finishing

8-page booklet describes Pylumin proces protecting aluminum, either painted or unpai *Pyrene Mfg. Co.*

121. Forging

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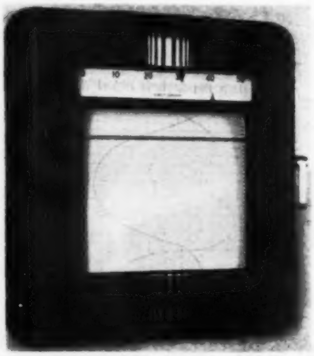

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WHAT'S NEW
IN MANUFACTURERS' LITERAT

122. Furnace
Bulletin HD-341 describes all-purpose multi-range box-type convection furnace for drawing, tempering and annealing of non-ferrous metals, aluminum brazing, annealing cast iron, normalizing and hardening of steels. *Hevi Duty Electric Co.*

123. Furnace Controls
Information available on the new recorder that automatically plots the relationship between two variables, showing one as a function of the other. Tedious compilation and manual plotting by experienced personnel are eliminated. *Leeds & Northrup Co.*

124. Furnaces
New bulletin 84P describes eight sizes in gas or electric models as well as complete line of conveyorized and batch or pot-type furnaces. *Despatch Oven Co.*

125. Furnaces
Catalog on Heroult gantry-type electric melting furnace with patented roof-ring to assure speedy and simple bricking and eliminate skew shapes. *American Bridge Co.*

126. Furnaces
Bulletin T-1420 illustrates and describes Lindberg LI-25 induction heating unit. A ruggedly constructed vacuum-tube type of unit for hard working production-line jobs. Ideal for hardening, brazing and soldering annealing and other induction heating applications. *Lindberg Engineering Co.*

127. Furnaces, Industrial
6-page folder describes 18 typical installations of gas-fired, oil-fired and electric furnaces of various types, complete with specially designed equipment for bright annealing, scale-free hardening, carbon restoration, carburizing and production heat treatment. *Electric Furnace Co.*

128. Furnaces, Reciprocating
Bulletin 815-AB completely describes versatile continuous reciprocating furnaces with positive atmosphere control for economical production heat treating. *American Gas Furnace Co.*

129. Hardness Testers
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

130. Heat Treating
Bulletin 123 describes how production is doubled, surface protection improved, and life of tools increased through the use of Ajax salt bath heat treating equipment. *Ajax Electric Co.*

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131. Heat Treating
New bulletin T-205 lists 118 patterns available in round and rectangular heat treating pots, X-rayed and pressure tested, for sound and economical service. *Electro-Alloys Div.*

132. Heat Treating
New bulletin, "Heat Treat Review", is designed to provide up-to-date information on heat treating processes as applied to all phases of the metal-working field. *Surface Combustion Corp.*

133. Heat Treating
Pressed steel lightweight sheet alloy heat treating units furnished in any size, design or specification. Write for full information on this. *The Pressed Steel Co.*

134. Heat Treating Service
New bulletin just released describes prompt service to heat treating customers for bright hardening and annealing of all hardenable grades of stainless steel including 410, 416, 420, and 440. *Drever Co.*

135. High Speed Steels
New booklet, "Why Desegatized", shows how these hi-carbon hi-chrome steels help to cut production costs with thorough carbide distribution providing extra toughness and strength. *Latrobe Electric Steel Co.*

136. Hi-Temperature Alloys
New edition of "Haynes Alloys for High-Temperature Service" summarizes all available data on 10 super-alloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite Div.*

137. High-Temperature Testing
For precise hi-temperature testing send for illustrated technical folder on Marshall equipment. *L. H. Marshall Co.*

138. Illuminated Magnifier
New illustrated folder lists various types of illuminated magnifiers for accurate inspection, along with photographs and prices. *E. W. Pike & Co.*

139. Immersion Heating
Bulletin IE-11 gives complete details on how new immersion pots save time and money in melting soft metals. High thermal efficiency for both large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg. Co.*

140. Industrial Planning
New book 127 tells how you can share in a "round-table" discussion of planning expansion, remodeling or modernization of your plant. *Continental Industrial Engineers, Inc.*

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WHAT'S NEW

IN MANUFACTURERS' LITERATU

141. Laboratory Safety

Newly revised edition of 40-page booklet includes recently developed data, techniques and equipment, and provides useful manual for setting up complete laboratory safety programs. *Fisher Scientific Co.*

142. Lubrication of Hot Metals

New bulletin 426 describes how colloidal graphite can solve your lubrication problems in hot metal-forming operations. *Acheson Colloids Corp.*

143. Metal Cleaning

Revised and enlarged edition of "An Introduction to Electrolytic Cleaning" contains latest information on various electrolytic cleaning processes, including cleaning of die-cast metals, cuprous metals reverse current cleaning, soaker tank cleaning and paint stripping. *DuBois Co.*

144. Metal Cutting

New 64-page catalog gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric Co.*

145. Metallography

Catalog E-210 describes photomicrography equipment model L, with proper accessories to meet all requirements for high and low photocopying. *Bausch & Lomb Optical Co.*

146. Metal-Treating Ammonia

Bulletins available on "Ammonia Installations for Metal Treating", "Effective Use of Dissociated Ammonia", "Carbonitriding of Steel" and "Nitriding Process". *Armour Ammonia Div.*

147. Microcasting

New color-illustrated folder, "Microcast Case Histories", describes microcasting applications for both industrial and defense requirements. *Austenal Laboratories, Inc.*

148. Oil Quenching

New folder available on oil quenching without distortion, using hot oil at temperatures up to 350°F, without undue thickening or oxidation. *E. F. Houghton & Co.*

149. Organic Solvents

64-page handbook packed with information including hundreds of definitions, comparison tables, testing methods and product descriptions on a wide variety of organic solvents in common use. Pocket size for easy reference. *The Solvents & Chemicals Group.*

150. Ovens

Portable Core Ovens is the subject of new bulletin 206. Shelf-type and rolling drawer ovens with recirculating heating systems for gas, oil or electricity are illustrated and described. *Foundry Equipment Co.*

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METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

February, 1951

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Company

Products Manufactu

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City and State

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Students

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

141. Laboratory Safety
Newly revised edition of 40-page booklet includes recently developed data, techniques and equipment, and provides useful manual for setting up complete laboratory safety programs. *Fisher Scientific Co.*

142. Lubrication of Hot Metals
New bulletin 426 describes how colloidal graphite can solve your lubrication problems in hot metal-forming operations. *Acheson Colloids Corp.*

143. Metal Cleaning
Revised and enlarged edition of "An Introduction to Electrolytic Cleaning" contains latest information on various electrolytic cleaning processes, including cleaning of die-cast metals, cuprous metals reverse current cleaning, soaker tank cleaning and paint stripping. *DuBois Co.*

144. Metal Cutting
New 64-page catalog gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric Co.*

145. Metallography
Catalog E-210 describes photomicrography equipment model L, with proper accessories to meet all requirements for high and low photocopying. *Bausch & Lomb Optical Co.*

146. Metal-Treating Ammonia
Bulletins available on "Ammonia Installations for Metal Treating", "Effective Use of Dissociated Ammonia", "Carbonitriding of Steel" and "Nitriding Process". *Armour Ammonia Div.*

147. Microcasting
New color-illustrated folder, "Microcast Case Histories", describes microcasting applications for both industrial and defense requirements. *Austenal Laboratories, Inc.*

148. Oil Quenching
New folder available on oil quenching without distortion, using hot oil at temperatures up to 350°F, without undue thickening or oxidation. *E. F. Houghton & Co.*

149. Organic Solvents
64-page handbook packed with information including hundreds of definitions, comparison tables, testing methods and product descriptions on a wide variety of organic solvents in common use. Pocket size for easy reference. *The Solvents & Chemicals Group.*

150. Ovens
Portable Core Ovens is the subject of new bulletin 206. Shelf-type and rolling drawer ovens with recirculating heating systems for gas, oil or electricity are illustrated and described. *Foundry Equipment Co.*

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METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

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Please have literature circled at the left sent to me.

Name ____________________ Title ____________

Company ____________________

Products Manufactured ____________________

Address ____________________

City and State ____________________

Postcard must be mailed prior to May 1, 1951—
Students should write direct to manufacturers.

OILITE may relieve your shortage of critical materials

Particularly in mass-production units of small and medium size, Oilite finished machine parts and bearings can be made to your design in a broad range of ferrous and nonferrous metals and alloys, except as limited by government control. Moreover, Oilite products of ferrous base may serve excellently instead of scarce nonferrous units or as replacements for steel and castings.

When you employ Oilite you also obtain the benefits of more than 20 years' engineering, research, and production experience in powder metallurgy, together with the service of field engineers throughout the United States and Canada.

You are invited to contact the field engineer in your district or write the home office regarding the application to your needs of Oilite products.

AMPLEX MANUFACTURING COMPANY

Subsidiary of Chrysler Corporation

DETROIT 31, MICHIGAN

Field Engineers and Supply Depots in Principal U. S. and Canadian Cities

OILITE PRODUCTS

Heavy duty, oil-cushioned, self-lubricating bearings and finished machine parts in ferrous and nonferrous metals and alloys. Permanent filters. Friction units. Self-lubricating cored and bar stock.

A Note to Executives

Oilite is an effective replacement, not a mere substitute

In the last decade, more and more executives have become "Oilite minded" because the advantages are many. To meet the current situation, many of our customers have changed their specifications to replace strategic copper and tin with products of iron powder or iron powder alloys. Others are replacing iron castings, steel and aluminum with similar Oilite products.

Also of importance to executives, under conditions of urgency, are the wide adaptability, the speed of delivery, and the economy of cost, time and manpower which result from the use of Oilite finished machine parts, made from metal powders.

Intricate designs, which normally require many different machining operations, can be produced quickly and economically from Oilite. There is great freedom of design and frequently two or more parts can be combined in a single Oilite unit. Oilite eliminates up to 24 machining operations.

Delivered ready for assembly, Oilite parts save the time and investment required to tool up by standard methods. It is not unusual to be in production on a complex Oilite part within a few weeks, as compared to a possible 18-month delivery of machine tools. Trained manpower is thus released for other urgent needs.

Oilite is not a substitute. It is metallurgy's answer to the need for a new material. It may solve your problem.

President

OILITE PRODUCTS

He's *Watching a Wedding* of metal and plastic

IN this high vacuum coating chamber, metal evaporates from a heated crucible and condenses on molded plastic items or sheeting. Result: precious metal lustre at dime-store price—beautiful enough for the appointments of a fine automobile, uniform enough for the condensers in America's telephone system.

DPi not only supplies all the equipment you need for the process but works closely with manufacturers in selecting undercoating and overcoating lacquers and the best procedure for each particular production problem.

The high vacuum chambers used for metal deposition are available in a large variety of sizes from a simple 12-inch glass jar to a stainless steel chamber 4 feet in diameter and nearly 5 feet long, complete with versatile electrical connections and instrumentation. Industry is using them profitably in many applications besides coating—high altitude studies, experimental design of electronic tubes, exploration of new production techniques in impregnation that would never have been practicable before high vacuum became so economical to obtain.

We've prepared a new data sheet that gives full engineering details about DPi's line of high vacuum chambers. That and an article discussing the technique and economics of metal coating on plastics are yours for the asking. Write ***Distillation Products Industries,*** Vacuum Equipment Department, 753 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

DPi

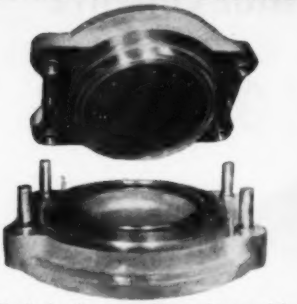
high vacuum research and engineering

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3400 Eastman Organic Chemicals for science and industry

Tool Steel Topics

BETHLEHEM STEEL

TOOLS MADE OF 67 CHISEL WITHSTAND BRUTAL SHOCK



A-H5 solved a distortion problem and increased the production of large dies for blanking tank heads.

A-H5 Cures Distortion of Large Blanking Dies

A manufacturer of water-heaters couldn't seem to prevent an excessive amount of distortion in large-diameter forged rings of oil-hardening steel for blanking out heads for water tanks. Our distributor recommended A-H5 (5 pct chrome, air-hardening) tool steel because of its greater resistance to distortion . . . and its added features of high wear-resistance and toughness.

After A-H5 had been used for one year, the records showed that besides licking the distortion problem, the air-hardening grade had made possible a nice increase in production . . . and the cost of the tool steel was no greater than before.

A-H5 is an economical, general-purpose grade—especially for tools and dies that call for long wear, high resistance to distortion, and for extra safety in hardening.

Our Tool Steel Engineer Says:

There are good reasons for annealing tool steel

Most tool steel bars are furnished in the annealed condition. The annealing is done for two reasons:

1. To remove the stresses in the as-rolled or as-forged bars which could otherwise lead to cracking.
2. To produce the lowest possible hardness consistent with the best machinability.

During the annealing operation, care must be used to avoid excessive scaling and decarburization. The bell-type, controlled-atmosphere furnaces used in our tool-steel mill are ideal for this purpose. We can far surpass the results obtained with ordinary annealing equipment.

67 Chisel, used in this punch, absorbs plenty of shock in the forming of parts from 0.185-in. sheet steel.

As its name implies, 67 Chisel is primarily for shock tools . . . but chisels account for only a small proportion of its many applications. This chrome-tungsten steel has high shock-resistance, good red-hardness, and it is readily carburized for high wear-resistance.

67 Chisel is first choice for master hobs used in hobbing molds for plastics and die-casting work. It's often used for punches, swaging dies, calking and beading tools . . . heavy shear blades for cold work and for hot work up to 1000 F . . . and various shock and hot-work jobs such as studs and bolts for elevated temperatures, drop-forge die inserts, piercers, headers, and forming tools.

Carburizing produces a high surface-hardness that's reinforced by a tough, shock-resisting core. 67 Chisel has very high impact properties—about 175 ft-lb. That's really tough!

67 Chisel is a mighty versatile grade to keep in mind when you need tools that will stand up under heavy shock or high pressures; and it's especially recommended for tools having deep recesses, corners, slender shanks—wherever great strength is needed. You'll find it's an easy steel to machine and heat-treat.

67 Chisel is stocked in many sizes and sections in our mill depot . . . also by distributors of Bethlehem Tool Steels in principal cities.

This die, used for "dimpling" aluminum aircraft skin, is made of 67 Chisel and is heated electrically to 600 F so as to stress-relieve the aluminum during the operation.

Made of 67 Chisel, this intricate master hob is used to hob a mold cavity for die-casting a multiple gear.

Choose Tool Steel To Fit the Job

Shop men sometimes have deep-rooted ideas about tool steel that just aren't based on facts. The other day, for example, we saw a milling cutter made for a rather unusual machining job. The toolmaker had selected high-speed steel, figuring it would last longest because it was the most expensive and the most highly alloyed grade.

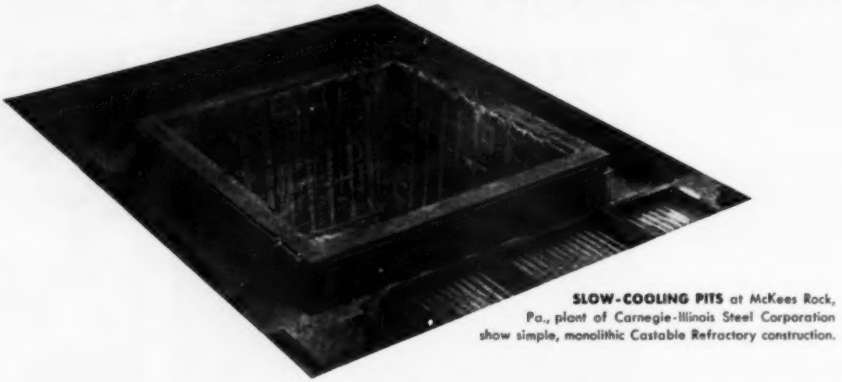
He made a poor choice, for the high-speed cutter produced only 18 pieces before it failed. One of our tool-steel engineers was called on to explain this disappointing performance. He recommended Bethlehem XX Carbon Tool Steel . . . and the first cutter made from it finished 175 pieces.

It's just another instance of the longer tool life made possible by selecting the right grade of tool steel for the job. Our technical staff is always ready to assist in selecting tool steels and in recommending the best methods of heat-treating.

Bethlehem ULTRASONIC TESTED **Tool Steel**

Need Refractories *FAST?*

Cast them on the job using a Castable Refractory made with LUMNITE*



SLOW-COOLING PITS at McKees Rock, Pa., plant of Carnegie-Illinois Steel Corporation show simple, monolithic Castable Refractory construction.

IF YOU'RE IN A HURRY to replace slow cooling pits, car tops, furnace doors . . . practically any refractory shape . . . use Castable Refractories made with Lumnite. They reach full service strength in 24 hours or less!

Castables are easy to use. No skilled labor necessary. They come to you dry, a balanced mixture of aggregates and Lumnite calcium-aluminate cement. All you do is add water and pour into place. Your job will be finished and into production—fast!

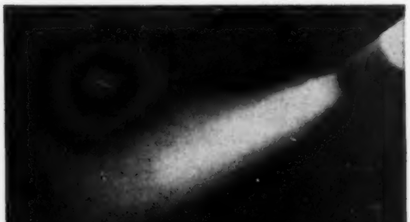
SPECIAL REQUIREMENTS? Tricky insulation or temperature problems? Castables solve them because they're available with a variety of specially selected aggregates for different temperature ranges.

Castable construction is simple. Monolithic walls replace hundreds of vulnerable joints and shapes. No daubing with mortar. And no cracks or joints to lose heat.

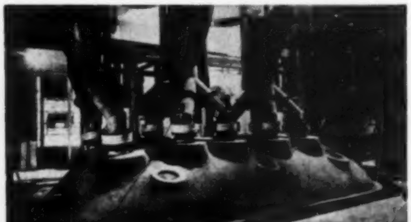
IF REPAIRS ARE NECESSARY, they can be made quickly, easily. The men in your own plant can mix and place the Castables. Outage time is cut to a minimum.

On your next job, specify Castable Refractories made with Lumnite. You're assured of a uniform product made with carefully selected aggregates. Castables are made by refractory manufacturers and sold by their dealers.

For further information, write Lumnite Division, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, N. Y.



STEEL STACK gets a protective lining of Castable Refractory Concrete. This lining resists high temperatures and attacks of condensate and sulphurous gases.



ADAPTABLE Castable Refractories can be cast into any shape or size. A good example is this 120-ton electric-arc furnace for phosphate reduction, located at TVA's Wilson Dam in Alabama

"LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

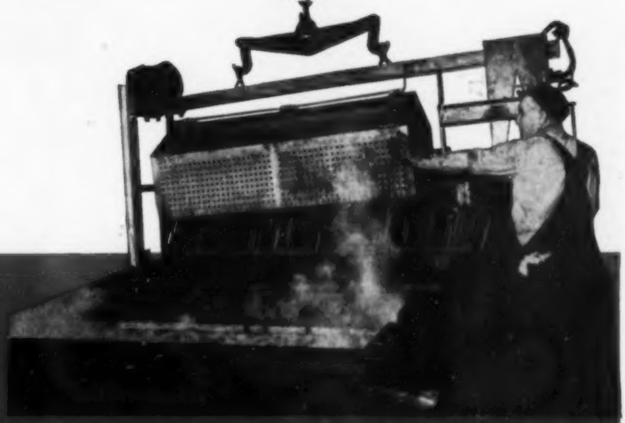
MP-L-41

ATLAS® **LUMNITE for INDUSTRIAL CONCRETES**

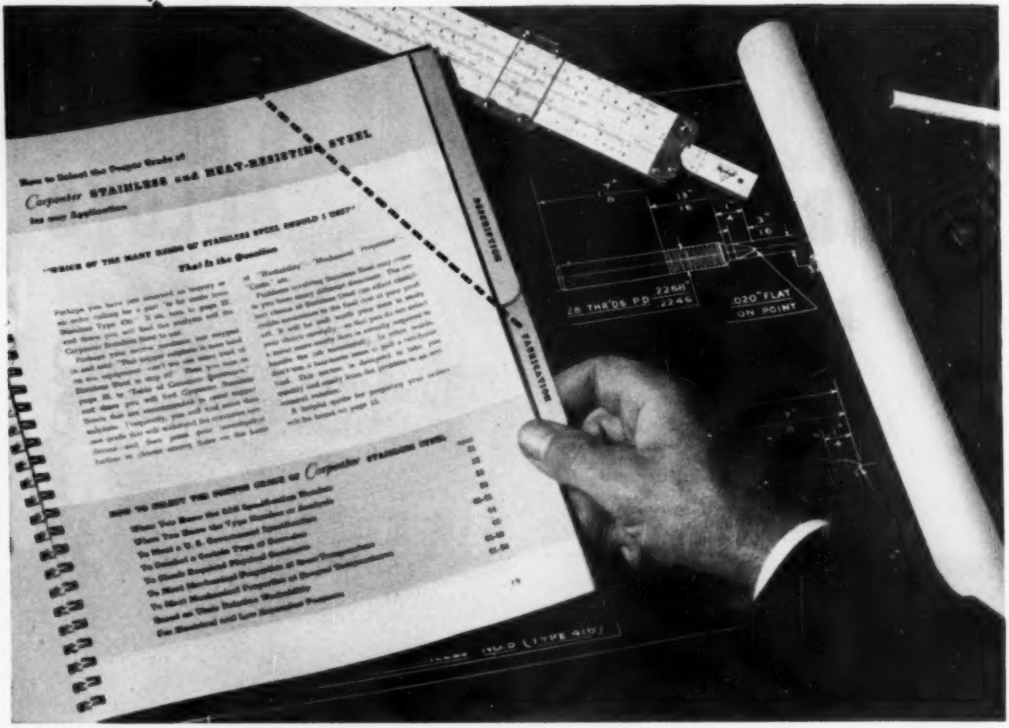
REFRACTORY, INSULATING, OVERNIGHT, CORROSION-RESISTANT

A UNIVERSAL ATLAS PRODUCT

"THE THEATRE GUILD ON THE AIR"—*Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—NBC Network*



X MARKS THE SPOT



Where You'll Find Answers to Your Questions about Stainless

We've taken our own experience in making Stainless—added a lot that we've learned about fabricating Stainless—and put it in this 133-page Working Data Book.

To put this book of combined experience to work for you, to get a greater number of perfect parts from every pound of Stainless you buy, call your Carpenter representative and ask for a copy of the Stainless Working Data Book. If you don't already have a copy, he'll be glad to give you one. And when you talk to him, put him to work on any special problems you may have. He knows a lot about Stainless. And he is backed up by mill men who have spent their lives digging for ways to do Stainless jobs better.

Make full use of Carpenter's service to users of Stainless. Call your nearest Carpenter office today for a copy of "Working Data for Carpenter Stainless and Heat Resisting Steels" . . . or for personal attention to a specific problem.

The Carpenter Steel Company, 133 W. Bern St., Reading, Pa.
Export Department: Woolworth Bldg., New York 7, N.Y.—"CARSTEELCO"

Carpenter
STAINLESS STEEL
takes the problems out of production

more than corrosion resistance

For Easy-to-Use Stainless Call Carpenter. Warehouses in principal cities throughout the country.

YES, IT'S *Yoloy*

Photo by courtesy of
Gramm Trailer Corp.

High-tensile steel transport trailer aerates and discharges dry bulk load in minutes

FAST unloading is a feature of this huge transport trailer. By simple but unique use of the principle of aeration, it discharges a cargo of cement or other dry, powdered, bulk material in just a few minutes. The trailer body is tilted as you see it here, low-pressure air is pumped through the load from below, and the "liquefied" dry cement flows out like water.

By using Yoloy high-strength steel for the frameless body, the manufacturer reduced dead weight over 20%, thereby making possible a much greater payload, as well as simplifying unloading and manipulation of the vehicle on and off the road.

Yoloy is Youngstown's low-alloy nickel-copper steel. It is tough, shock-resistant, corrosion-resistant and wear-resistant---properties which permit its use in thinner, lighter weight sheets and members than is customary with ordinary steels. These important advantages of Yoloy are leading to its ever widening use where it is important to reduce weight, corrosion, wear and cost without sacrificing strength or utility.

Yoloy is now available in sheets, plates, strip, bars, shapes, cold drawn bars and tubular products, including both seamless and continuous weld pipe in a number of wanted sizes. Call the nearest Youngstown District Sales Office or write us direct for full information on "Youngstown" Yoloy high tensile steel.

Youngstown
YOLOY STEEL

QUALITY YOUNGSTOWN SERVICE

THE YOUNGSTOWN SHEET AND TUBE COMPANY General Offices — Youngstown 1, Ohio

Manufacturers of Carbon, Alloy and Yoloy Steel Export Office - 500 Fifth Avenue, New York

PIPE AND TUBULAR PRODUCTS - WIRE - ELECTROLYTIC TIN PLATE - COKE TIN PLATE - HOT AND COLD FINISHED CARBON AND ALLOY BARS - RODS - SHEETS - PLATES - CONDUIT - RAILROAD TRACK SPIKES.

NU-SAL AND THERMO-QUENCH ... two Park *laboratory controlled* heat-treating salts that make an unbeatable team on interrupted quenching operations!

Nu-Sal, you know, possesses unusually high thermal-conductivity. It provides rapid, uniform heating that assures consistently good results and its working range covers the hardening temperatures of most commonly used steels. In addition, you'll find that Park Nu-Sal forms an exceptionally fluid austenitizing bath of great fluidity and miscibility.

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ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

VANADIUM...the metal that accentuates the effects of other alloying elements

Vanadium is usually added to steel or iron along with other alloying metals, such as manganese, tungsten, nickel, or chromium. It enhances the effect of these other alloys and helps to improve the physical properties of the metal. Generally it is used in quantities of less than 0.50 per cent, but even in these small amounts it is responsible for many marked improvements in the quality of iron and steel.

One of the most notable functions of vanadium is its effect in improving the dynamic properties of steel, such as fatigue and impact resistance. It also gives an inherently fine grain size to both steel and iron.

In high-speed tools, vanadium contributes wear resistance and red hardness. It is also an important alloy in many types of permanent magnet steels. These and many other types of special-purpose steels contain more than 0.50 per cent vanadium to enhance certain properties.

Dynamic Strength for Steels

The principal effect of vanadium in engineering steels is that of refining grain size. It is usually added in amounts of 0.10 to 0.25 per cent.

Fig. 1. Steels in which vanadium is an alloy have outstanding dynamic strength. That is why they are frequently used in such heavy-duty service as springs and axles in diesel locomotive trucks.

In the lower carbon ranges, vanadium steels are especially suited for carburizing and are used for such applications as hand tools, bearings, and pistons. Vanadium-bearing steels can also be nitrided effectively.

Vanadium contributes fatigue and impact resistance and also strength and ductility to spring steels. The famous chromium-vanadium (SAE 6100 series) and manganese-vanadium spring steels are outstanding examples of this use. Besides being used as springs, these steels are frequently used for axles, shafts, and other highly stressed moving engine parts.

Red Hardness in Tools

Practically all fine tool steels contain vanadium. In high-speed steels, vanadium content usually ranges from about 0.50 to 2.50 per cent, although higher percentages are sometimes used. Other alloy tool steels usually contain from 0.20 to 1.00 per cent vanadium.

Vanadium is a strong carbide-former and forms very hard and stable carbides. These vanadium-carbides are probably the main reason for the excellent wear resistance and edge-holding properties of vanadium tool steels. The persistence of the vanadium-carbides is largely responsible for the cutting qualities at red hardness of high-speed tool steels.

Adds Strength to Cast Iron

In amounts of 0.10 to 0.15 per cent, vanadium increases the strength of cast iron from 10 to 25 per cent, and adds a considerable amount of toughness. Cast iron containing vanadium is especially valuable in such applications as steam locomotive cylinders, valve and piston bushings, piston rings, and similar parts. In steam engines and diesel motors, vanadium cast iron cylinders greatly outlast those of ordinary cast iron. Chromium-vanadium cast iron rolls, containing up to 2 per cent chromium, have been used successfully in steel mills for a great many years.

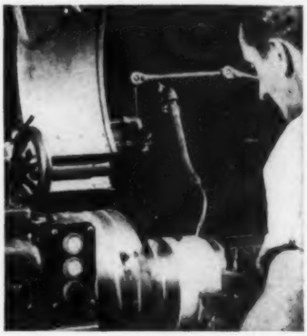

Fig. 2. Nearly all fine tool steels contain vanadium. It promotes fine grain size, high wear resistance, and greater control of hardenability. Vanadium also contributes to the red hardness of high-speed tool steels.

Cast iron in which vanadium is the sole alloying element is used primarily in applications where temperatures are moderately high and in heavy sections requiring uniform hardness without brittleness.

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ELECTROMET produces three grades of ferrovanadium in various sizes for the production of vanadium-bearing steels and irons. Each grade has a definite range of carbon and silicon contents and is especially adapted to assure the best results in the different requirements of iron and steelmaking.

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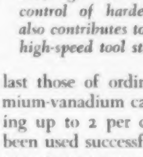

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February, 1951

Volume 59, No. 2

Metal Progress

Cover (Wire Pick-Up Reels) by Elicia Borja

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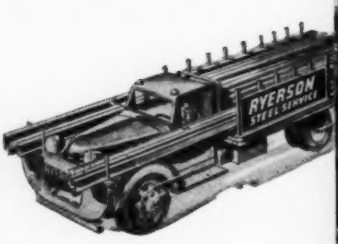
Critical Points, by the Editor

Abstracts of Important Articles

At right, one of the many building projects in the current Ryerson expansion program.



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By W. O. Binder
Research Metallurgist
Electro Metallurgical Division
Union Carbide and Carbon Corp.
Niagara Falls, N. Y.

Interchangeability of Cb and Ta in Type 347 Stainless

COLUMBIUM has been used to prevent the development of intergranular corrosion in the 18% chromium, 8% nickel steels for a number of years. Its further application to high-temperature alloys has created a large demand for the metal, and it has become necessary to seek aid from other elements to avoid failure in austenitic Cr-Ni steels from intergranular attack. It has long been recognized that tantalum is one such effective agent, and an investigation has been made to ascertain the influence of tantalum alone, and tantalum and columbium together in preventing intergranular attack. Our studies were carried out on 18-8 steels containing between 0.035 and 0.07% carbon using *(a)* tantalum metal, *(b)* the well-known ferrocolumbium alloy containing approximately 55% columbium and 5 to 7% tantalum, and *(c)* a new ferro-alloy containing about 40% columbium and 20% tantalum. The object was to determine *(a)* the equivalency of tantalum with respect to columbium in preventing intergranular attack in 18-8 steels, *(b)* the probable ratio of columbium + tantalum to carbon required for practical immunity to intergranular attack, and *(c)* the effect of a partial substitution of tantalum for columbium on the strength and ductility of the normal columbium-bearing 18-8 steel at room and elevated temperatures.

Experimental Conditions — All the steels employed in the test program were melted from virgin raw materials of high-grade commercial quality in a small, magnesia lined, high-frequency furnace. The melts were cast into 2-in. square ingots that were hot rolled to ¼-in. plate and 0.06-in. strip, and subsequently annealed 15 min. at 1965° F. (1075° C.) and air cooled. Carbon varied from about 0.035 to 0.07%, nickel from 10.75 to 11.75%, and chromium from 18 to 19%. Melts were deoxidized by adding 1.5% manganese and 0.5% silicon.

One sensitizing heat treatment of relatively short duration and one of longer duration were utilized to determine resistance to intergranular corrosion, since steels subjected to high temperatures during fabrication only do not require the same capacity to resist intergranular attack as do steels exposed for long periods. The treatment chosen to represent cycles of short duration was 2 hr. at 1200° F. (650° C.); the one selected for long-time heating was 24 hr. at the same temperature.

Three test media were utilized for measuring intergranular susceptibility, namely, boiling 65% nitric acid, a solution of 10% nitric acid and 3% hydrofluoric acid at 70° C., and a boiling acidified copper sulphate solution (50 g. $CuSO_4 \cdot 5\,H_2O$ plus 50 cc. concentrated H_2SO_4 plus 420 cc. water). Samples were immersed in nitric acid for five periods of 48 hr. each, and the ones in nitric-hydrofluoric acid were for five periods of 1 hr. each. The steels were boiled in the copper sulphate solution for a total period of 700 hr. unless extensive intergranular attack occurred earlier.

Tantalum Equivalency — As a carbide former, tantalum is theoretically 0.513 times as effective as columbium because of its higher molecular weight. While the validity of this ratio has been well established for the formation of pure tantalum carbide and columbium carbide, it was considered desirable to make an experimental determination of this equivalency

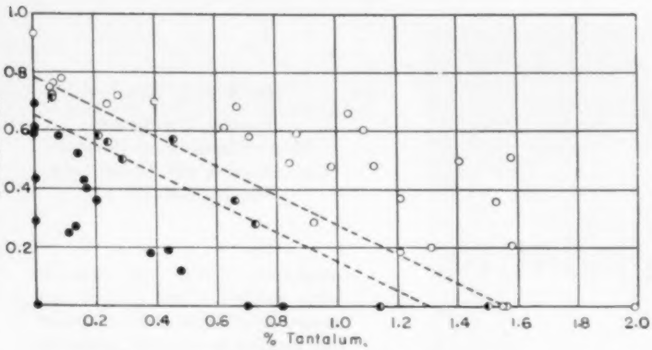

Fig. 1 — Effect of Ta and Cb on Intergranular Corrosion Resistance of 18-8 With 0.055 to 0.065% C

HEAT TREATMENT: 15 min. at 1965° F., air cool, 24 hr. at 1200° F., air cool.
CORRODENT: Nitric-hydrofluoric solution at 70° C., five 1-hr. periods.
OPEN CIRCLES: Equal corrosion rates in annealed and in sensitized samples.
SEMISOLID CIRCLES: Difference less than 0.5-in. penetration per month.
SOLID CIRCLES: Difference greater than 0.5-in. penetration per month.

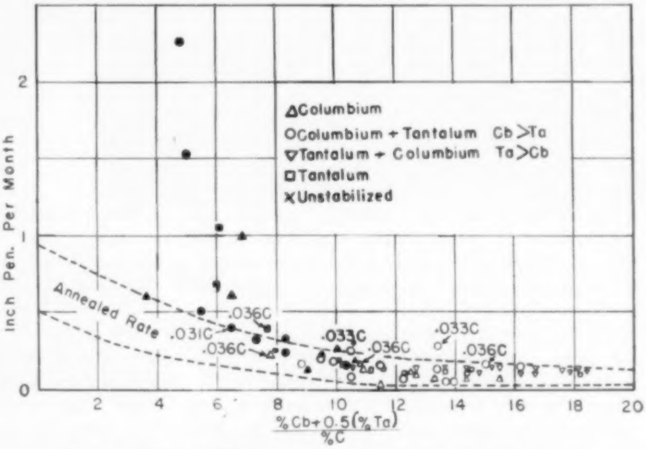

Fig. 2 — Effect of Ratio of (Cb, Ta) to Carbon on Intergranular Corrosion Resistance of 18-8 With 0.030 to 0.065 C

CONDITIONS same as in Fig. 1 except heated only 2 hr. at 1200° F.
SOLID CIRCLES represent samples showing signs of intergranular attack.
UNSTABILIZED sample (no Cb) corroded 7.55 in. per month.
ANNEALED RATE limits parallel corrosion tests on samples annealed only.

in preventing intergranular attack in 18-8 steel, since the presence of one or the other metal might affect the ratio significantly.

The factor of equivalency has been experimentally determined by superposing on a composition chart wherein % Ta is plotted against % Cb the results of corrosion tests made on 18-8 steels containing 0.055 to 0.065% carbon and various percentages of columbium and tantalum. The corrosion data were the results of weight-loss and bend tests made on samples exposed to nitric-hydrofluoric acid solution at 70° C. after heating 24 hr. at 1200° F. (650° C.). It should be emphasized that these test conditions are extremely severe, and clearly show the effects of columbium and tantalum on the resistance of the 18-8 stainless steel to intergranular attack.

One of the scatter plots obtained is presented in Fig. 1, wherein the criterion is the equality of weight loss in "sensitized" samples and annealed samples. It reveals that steels immune to more rapid attack when "sensitized" lie to the right of a straight line connecting 0.78% columbium and 1.56% tantalum. When consideration is given to the severity of the test conditions, it is clear that the lower dividing line drawn in Fig. 1 between 0.65% columbium and 1.30% tantalum will suffice, because the degree of attack exhibited by the few steels falling in the intermediate region is very small. Experience with the normal Type 347 steel (columbium stabilized 18-10) also shows that, for service conditions, a minimum ratio of columbium to carbon higher than 10 is unnecessary.

The relative effectiveness of tantalum with respect to columbium in preventing intergranular attack has been calculated from the slope of the line dividing the region of susceptibility from the region of no attack. Obviously, tantalum on a weight basis is half as effective as columbium. The value of the factor determined in this manner is in excellent agreement with the stoichiometric calculation based on the chemical formulas of tantalum carbide and columbium carbide.

An X-ray diffraction study of carbide residues attempted to identify the type of carbides present in the steel. The residues were obtained by dissolving the steels (after heating 24 hr. at 650° C.) in a solution of copper-potassium chloride containing hydrochloric acid.

X-rays showed that the carbides of columbium and tantalum form a continuous series of solid solutions in 18-8 steel. The residue extracted from steels containing less than about 1.5% columbium and/or tantalum consisted of (CbTa)C, in agreement with the corrosion tests described above; however, when the total exceeded 1.5%, the M_6C carbide was observed in addition to (CbTa)C.

The actual amount of columbium and tantalum required for immunity is greater than the simple stoichiometric calculations indicate are necessary to combine with all the carbon. There are several reasons. Both columbium and tantalum form nitrides almost as readily as carbides. Since nitrogen was present — in some instances up to about 0.05% — about as much columbium and tantalum are required to combine with nitrogen as with carbon. In addition to this, some columbium and tantalum are soluble in austenite and are not available for combining with carbon and nitrogen. However, Fig. 1 indicates that the solubility of tantalum in steels with high columbium is probably not a very significant factor, since the addition of small amounts of tantalum to high-columbium steels reduces the corrosion rate after sensitizing.

A similar chart (not reproduced) plotted as in Fig. 1 shows the results of corrosion tests made on samples heated the shorter time — 2 hr. at 650° C. The corrosion damage caused by this heat treatment is much less severe than that produced by heating the steels 24 hr. at 650° C., and this is reflected in the lower columbium and tantalum contents required for immunity to attack. The region where the amount of attack is insignificant or absent lies above a straight line of slope −0.55 connecting 0.50% columbium and 0.90% tantalum. The equivalency factor derived from these tests is in good agreement with the factor based on samples heated 24 hr. at 650° C.

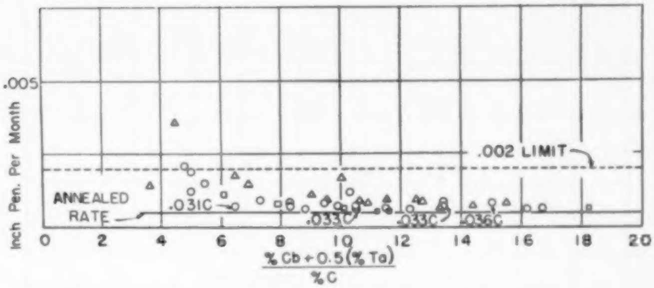

Fig. 3 — Effect of Ratio of (Cb, Ta) to Carbon on Resistance to Boiling 65% Nitric Acid, Five Periods of 48 Hr. Each. Conditions and legend same as in Fig. 2, except for corroding medium. Two unstabilized specimens corroded 0.0145 and 0.0175 in. per month

Practical Immunity

A large number of steels ranging from 0.035 to 0.065% carbon were tested during the course of this investigation. For the sake of clarity, the results obtained will be discussed according to their equivalent columbium-to-carbon ratio, using 0.5 as the factor for tantalum. Expressed algebraically this is

$$\frac{\%\ \text{Cb} + 0.5\ (\%\ \text{Ta})}{\%\ \text{C}}$$

In this phase of the work, consideration was given to the effect of short and long periods of heating in the sensitizing temperature range. Figure 3 summarizes the results of intergranular corrosion tests in nitric-hydrofluoric acid solution at 70° C. on samples heated 2 hr. at 1200° F. (650° C.). As previously stated, this treatment was selected to represent the effect on inter-

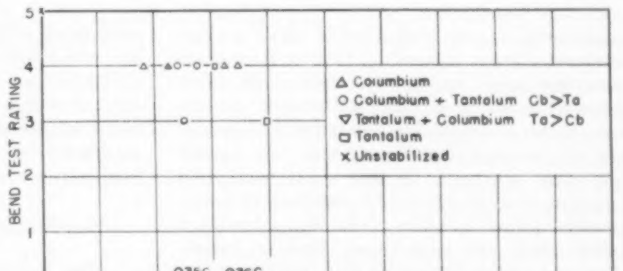

Fig. 4 — Bend Test Rating of Test Alloys After Sensitizing 2 Hr. at 1200° F. and Boiling 700 Hr. in Acidified Copper Sulphate Solution

Bend Test Ratings

Zero — No cracks
1 — Slight edge cracks
2 — Deep edge cracks
3 — Slight surface cracks
4 — Deep surface cracks
5 — Specimen broke

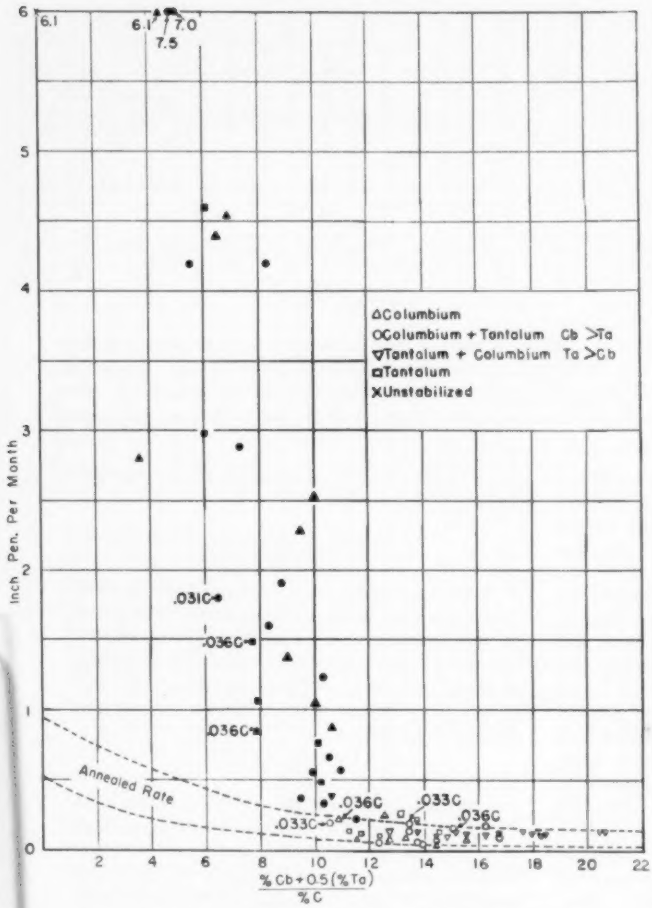

Fig. 5 — Effect of Ratio of (Cb, Ta) to Carbon on Intergranular Corrosion Resistance After 24 Hr. at 1200° F. (650° C)

HEAT TREATMENT: Same as in Fig. 1.
SOLID characters locate samples showing signs of intergranular attack.

granular corrosion resistance of short periods at elevated temperatures. It is clear from these data that steels having less than about seven times as much "equivalent columbium" as carbon exhibit susceptibility unless the carbon content of the steel is kept very low. An equally important conclusion is that steels containing tantalum are as effectively resistant to intergranular attack as steels containing columbium alone (when the equivalency between columbium and tantalum is taken into consideration). Since exposure to nitric-hydrofluoric acid constitutes a very severe test, it therefore appears that steels having a minimum ratio of about seven times carbon would be satisfactory for applications where the steel is not exposed to high temperatures during use.

Companion samples to those recorded in Fig. 2 were tested in boiling 65% nitric acid. The average corrosion rate obtained after five periods of 48 hr. each is plotted in Fig. 3 against the (Cb, Ta)/C ratio of the steel. Since the corrosion rate increases somewhat after the metal has been heated at 1200° F. (650° C.), it becomes necessary to set some maximum value as a guide, and 0.002 in. penetration per month was chosen. Figure 3 shows that the difference in corrosion rate in HNO_3 of metal in the annealed condition and in the sensitized condition decreases with increasing (Cb, Ta)/C ratio — toward the right of the chart. Tantalum is as effective as columbium in preventing intergranular corrosion (if due consideration is given to the fact that tantalum is only one half as effective as columbium) — note, for example, the low positions of the alloys stabilized with tantalum only (squares) or with tantalum-rich ferro (downward pointing triangles). As in the nitric-hydrofluoric acid tests shown in Fig. 2, it appears that, if period of exposure to temperatures in the sensitizing range is short, a minimum ratio of six or seven times the carbon is needed.

Figure 4 shows the bend test rating of the 18-8 steels under test after they had been heated 2 hr. at 1200° F. (650° C.) and then boiled 700 hr. in acidified copper sulphate solution. All the samples containing (Cb, Ta)/C > 7.0 rated zero except one which had 8 times the carbon in equivalent tantalum (no columbium). Again it may be concluded that a minimum ratio of stabilizing metal of about 7 times the carbon would be satisfactory when exposure of the steel to high temperatures is limited to short periods of time.

Simulating High-Temperature Service

The foregoing evaluates the intergranular corrosion resistance of the steels after short periods of heating, and should not be confused with the exposure of these steels under more severe conditions which will require greater resistance to intergranular corrosion. A

treatment consisting of 24 hr. at 1200° F. (650° C.) was selected as such a criterion. Samples so treated were then subjected to the three corrosive solutions already mentioned and the intergranular attack measured by weight loss (penetration) or by a bend test rating. These data are summarized in Fig. 5, 6 and 7.

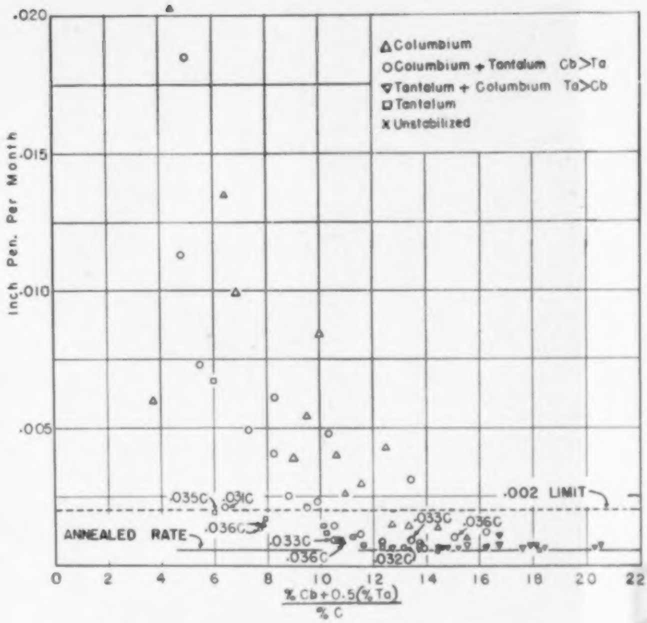

Fig. 6 — Samples of Same Steels as Fig. 5, Exposed to Five Periods of 48 Hr. Each in Boiling 65% HNO_3. Unstabilized sample lost at the rate of 0.033 in. per month

The large number of test results that show high corrodibility in the left portions of Fig. 5 and 6, and the poor bend test rating of many samples in Fig. 7, clearly indicate that when the steels are held for relatively long periods in the sensitizing temperature range, the ratio of (Cb, Ta)/C for practical immunity must be increased over the figure of 7.0 that is adequate for immunity to less severe circumstances. The damage due to intergranular corrosion by the nitric-hydrofluoric acid criterion, Fig. 5, decreases sharply when a ratio of 10 is reached. Even with increased ratios — up to 14 — a few steels are attacked by nitric acid and acidified copper sulphate (Fig. 6 and 7). Such results would be expected in view of the extreme severity of the test conditions, and (as in previous work) the evidence is strong that a minimum ratio of 10 times as much equivalent columbium as carbon is needed for practical immunity under long-time heat and corrosion conditions. Again, it is significant that tantalum is an effective carbide stabilizer, if its higher molecular weight is considered, as it is in this method of plotting the results.

Examination of Fig. 6 shows that steels containing tantalum generally tend to be more resistant to nitric acid after heating at 1200° F. (650° C.) than steels with columbium alone, particularly when the ratio falls below 10. This excellent resistance to nitric acid suggests that the solubility of TaC in 18-8 austenite may in part be responsible. As indicated in Table I, the corrosion of two sensitized heats (almost identical chemically except that one is stabilized with columbium and the other with equivalent tantalum) in nitric acid or in HNO_3-HF is related to the annealing temperature. Corrosion of the columbium-stabilized metal increases more rapidly than the tantalum-stabilized metal as the annealing temperature increases from 1965 to 2100 to 2280° F. This suggests that TaC is less soluble, or goes into solution more slowly than CbC with higher annealing temperatures.

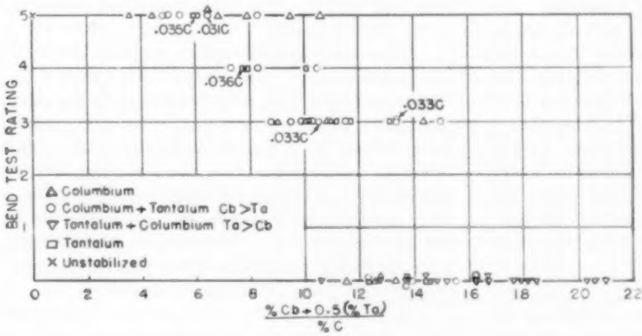

Fig. 7 — Companion Tests to Those of Fig. 4, Except That Samples Were Heated 24 Hr. (Instead of 2 Hr.) at 1200° F.

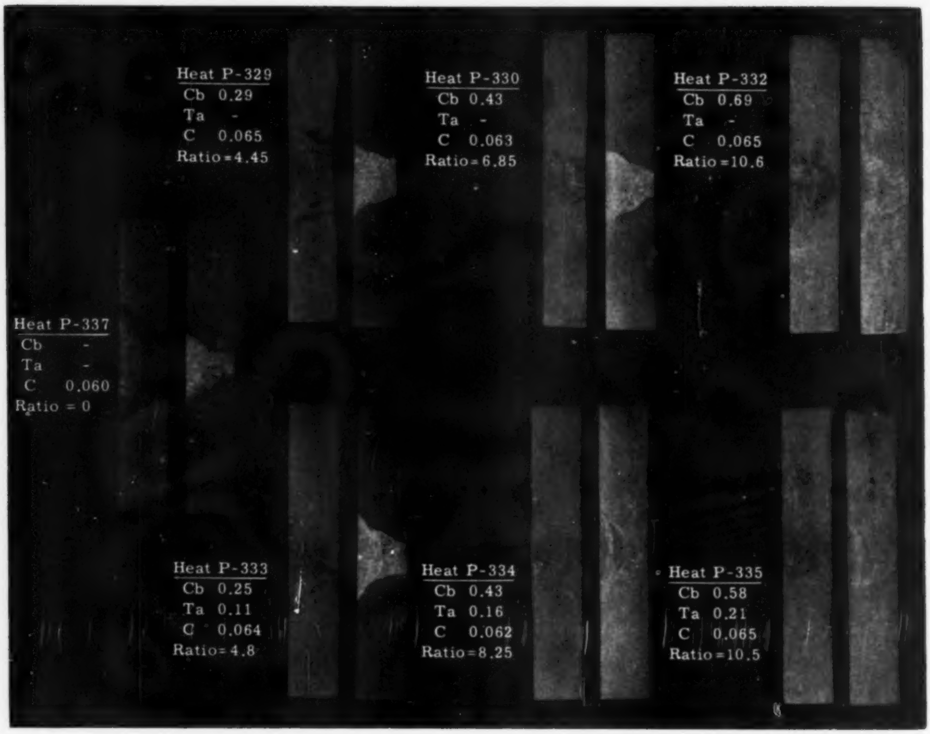

Fig. 8 — Welded Samples of Seven Heats of 18-8 With 0.06% Carbon and Various Amounts of Columbium and Tantalum, Exposed Five 1-Hr. Periods to HNO_3-HF Solution at 70° C. Left-hand sample as-welded; right-hand sample of each pair had been heated 2 hr. at 1600° F. (stress relieved)

Welding Tests

The tests summarized in the foregoing figures show that the minimum ratio of stabilizing element to carbon in the steel required for immunity to intergranular attack is dependent upon the time of heating in the sensitizing temperature range. These data represent isothermal heat treatments and may not, of course, simulate the conditions encountered in service, or even during fabrication. In welding, for example, the time of exposure to elevated temperatures can be much less than that employed in the shortest of our isothermal tests, and it would be anticipated that a somewhat lower ratio (Cb, Ta)/C could be employed when the steel is fabricated by welding and is not subjected thereafter to excessively high temperatures in service.

To ascertain the influence of welding heat on the intergranular corrosion resistance of steels stabilized with columbium and/or tantalum, several of the steels made for the foregoing tests were welded and their resistance to intergranular corrosion was determined in the as-welded condition and after stress relieving at 1600° F. (870° C.). Two series of steels were tested, one containing columbium and one containing both columbium and tantalum. In each series, carbon was held at two different levels, namely, between 0.045 and 0.055% and between 0.06 and 0.07%. The (Cb, Ta)/C ratios varied from about 4 to 10.

The experimental welds were made by butting together two ½-in. plates, each about 2 in. wide and 12 in. long, and joining them by multiple-pass hand-arc welding. Narrow plates were welded, as it was believed that this would intensify the conditions for intergranular attack. The steels containing columbium and tantalum were welded with commercial lime-coated Type 347 steel electrodes. Unstabilized steels, which were included for comparative purposes, were welded with Type 308 steel electrodes.

Left-hand samples of each pair in Fig. 8 show the appearance of several of the 0.06% carbon steel welds after exposure to the HNO_3-HF solution in the as-welded condition.

Table I — Effect of Annealing Temperature on Corrosion Rate of 18-8 When Cb Is Replaced by Ta

Anneal	Sensitized	Heat P-430, (Cb)		Heat P-389, (Ta)	
		HNO_3*	HNO_3-HF†	HNO_3*	HNO_3-HF†
15 min. @ 1075° C.	No	0.00046	0.19	0.00039	0.06
15 min. @ 1075° C.	Yes‡	0.00169	0.19	0.00057	0.06
15 min. @ 1150° C.	Yes‡	0.0037	0.15	0.00060	0.06
15 min. @ 1250° C.	Yes‡	0.0107	1.95	0.00172	0.45

*Rate in fifth 48-hr. period in boiling 65% HNO_3.
†Rate in 10% HNO_3 + 3% HF at 70° C.
‡24 hr. at 650° C. (1200° F.) and air cooled.

	Heat P-430	Heat P-389
Chromium	18.60%	18.00%
Nickel	10.75	11.75
Manganese	1.50	1.50
Silicon	0.35	0.35
Carbon	0.057	0.055
Nitrogen	0.046	0.048
Columbium	0.74	—
Tantalum	0.10	1.56

Steels having a ratio in excess of about 5.0 are immune to attack, showing that the ratio required after exposure to welding heat is significantly less than that required to meet a 2-hr. heat treatment at 650° C. (Fig. 2). In every case, the corrosion resistance after welding of the steels containing columbium and tantalum is the equivalent of Type 347 stainless with columbium only.

Another series of tests measured the damage which occurred in the 0.045 to 0.055% carbon series. Here again, the columbium-plus-tantalum steels behave as satisfactorily as the steels with columbium alone. These lower carbon steels have the advantage of immunity at a ratio of about 4.0 in as-welded condition.

In continuing these tests, samples from the experimental welds were heated 2 hr. at 1600° F. (870° C.) and air-cooled to determine the influence of stress-relieving following welding on the resistance of the steels to intergranular attack. The right-hand samples of each pair in Fig. 8 show the damage occurring in the same 0.06% carbon steels after testing in HNO_3-HF solution. This heat treatment caused the unstabilized steel to granulate excessively and some attack to occur in steels having ratios of 4.5 to 5, but steels with ratios in excess of about 6.0 were unaffected. Again, the corrosion resistance of the steels containing columbium plus tantalum were comparable to those containing columbium alone.

Similar tests on the 0.05% carbon steels showed that the minimum ratio was between 5 and 6 for stress-relieved samples.

As-welded pieces were also boiled in acidified copper sulphate solution for 700 hr., and the extent of damage was determined by a bend test in the heat affected area adjacent to the weld. The presence of tantalum in the 18-8 steel did not detrimentally affect cold ductility as measured in this way, since all steels containing tantalum elongated 40% on the bend without cracking. The heat affected zone of the plain 18-8 steel containing 0.06% carbon was only slightly attacked by this test medium, and the amount of damage was insignificant in comparison with nitric-hydrofluoric acid. Thus, it is not surprising that the *stabilized* steels showed no signs of attack in boiling copper sulphate solution. In similar tests the 0.05% carbon, as-welded, showed excellent resistance to intergranular attack with a ratio as low as 3.6.

Table II — Corrosion of Welded 18-8 in 65% HNO_3

Heat No.	Analysis			Ratio*	As-Welded		Welded + Stabilized†	
	% Cb	% Ta	% C		5th Period	Average	5th Period	Average
P-243-1	—	—	0.052	0	0.00058	0.00055‡	0.00356	0.00188**
P-244	0.16	0.04	0.053	3.6	0.00081	0.00071	0.00113	0.00087
P-248	0.18	0.13	0.045	5.5	0.00075	0.00069	0.00092	0.00078
P-245-1	0.29	0.04	0.048	6.5	0.00083	0.00076	0.00102	0.00085
P-249	0.27	0.15	0.047	7.3	0.00079	0.00072	0.00073	0.00069
P-247	0.47	0.10	0.048	10.9	0.00081	0.00073	0.00078	0.00081
P-250	0.38	0.24	0.053	9.5	0.00083	0.00073	0.00073	0.00069
P-337	—	—	0.06	0	0.00066	0.00067‡	0.00490	0.00257**
P-329	0.29	—	0.065	4.5	0.00075	0.00072	0.00216	0.00141
P-333	0.25	0.11	0.064	4.8	0.00072	0.00070	0.00156	0.00111
P-330	0.43	—	0.063	6.9	0.00071	0.00067	0.00124	0.00095
P-334	0.43	0.16	0.062	8.3	0.00075	0.00068	0.00076	0.00074
P-332	0.69	—	0.065	10.6	0.00076	0.00073	0.00072	0.00071
P-335	0.58	0.21	0.065	10.5	0.00063	0.00063	0.00066	0.00074

*(% Cb + 0.5% Ta) ÷ % C.
†Heated 2 hr. at 1600° F. (870° C.) and air cooled.
‡Very slight granulation of plate metal in heat affected zone.
**Plate metal granulating.

In the stress-relieved condition (heated 2 hr. at 1600° F.) the unstabilized steels crack excessively when bent after boiling in acidified copper sulphate solution, but no cracking was detectable in the stabilized steels.

As shown in Table II, the corrosion resistance adjacent to the welds in boiling 65% HNO_3 is comparable to the unwelded base metal. While some granulation was noted in the heat affected zone of the unstabilized steels, no attack was observed in any of the stabilized steels. These results indicated that the (Cb, Ta)/C ratio must be at least 6 in the 0.06% carbon steels to avoid an appreciable increase in the nitric acid corrosion rate after heating 2 hr. at 1600° F. (870° C.), and between 4 and 5 for the 0.05% carbon steels. It is obvious from these tests that, after welding, steels stabilized with columbium and tantalum are comparable in corrosion resistance to steels containing columbium alone.

While it thus appears that tantalum may be used in 18-8 steel in conjunction with columbium to inhibit intergranular corrosion if consideration is given to its higher molecular weight, the substitution of tantalum for columbium could have important implications on formability and elevated temperature properties. In order to determine this possibility, room temperature and elevated temperature tests were conducted on steels containing both elements.

Standard tensile specimens from 0.06-in. thick sheet were used in room temperature tests and in the short-time tensile tests at 1200° F. (650° C.). Results are summarized in Table III. Prior to testing, the steels were heated 10 to 15 min. at 1965° F. (1075° C.) and air cooled.

Inspection of the results shows that the room temperature strength and ductility of austenitic 18-8 steel containing 0.25 to 0.5% tantalum and 0.5 to 1% columbium are comparable to those for normal Type 347 steel (18-8 Cb), indicating that the partial replacement of columbium with tantalum should have no significant effect on the forming characteristics. The short-time tensile properties at 1200° F. (650° C.) of the tantalum-bearing steels are also in good agreement with those of normal Type 347.

Stress-to-rupture tests were made on five 18-8's containing columbium and

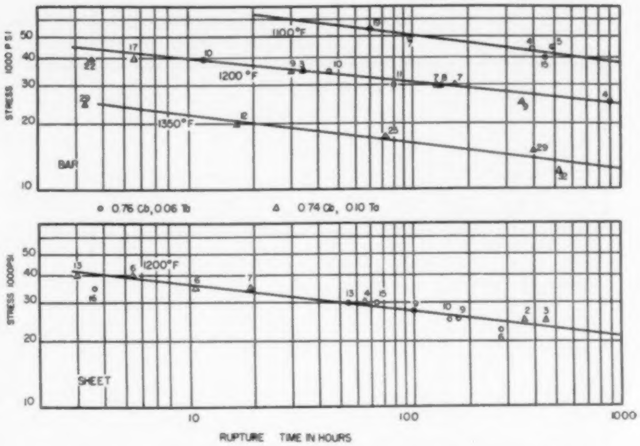

Fig. 9 — Stress-Rupture Curves for 18-8 Cb (Type 347) Stainless Bars at 1100, 1200 and 1350° F., and for 0.06-In. Sheet at 1200° F. Figures alongside points indicate % elongation

Table III — Tensile Properties of 18-8 Steels Containing Columbium and Tantalum

Heat No.	Composition			Room Temperature			At 1200° F. (650° C.)	
	Cb	Ta	C	Yield	Tensile	Elong.	Tensile	Elong.
M-944	0.71	0.06	0.059	39,100	87,900	47%	48,900	30%
P-430	0.74	0.10	0.057	38,400	91,000	44	53,300	20
P-267	0.48	0.27	0.046	39,900	88,500	49	50,000	22
M-893	0.50	0.29	0.056	40,000	91,300	47	—	—
P-280	0.60	0.26	0.057	37,100	90,300	51	51,200	25
P-268	0.98	0.46	0.046	39,700	87,600	50	48,500	27
P-281	1.00	0.40	0.057	38,500	89,400	46	48,700	28

Table IV — Stress-Rupture Properties of Type 347

Temperature	Type of Specimen	Stress Causing Fracture in	
		100 Hr.	1000 Hr.
1100° F., 593° C.	Bar	52,000 psi.	38,000 psi.
1200° F., 650° C.	Bar	31,000	24,500
1200° F., 650° C.	Sheet	28,000	21,000
1350° F., 734° C.	Bar	16,500	12,500

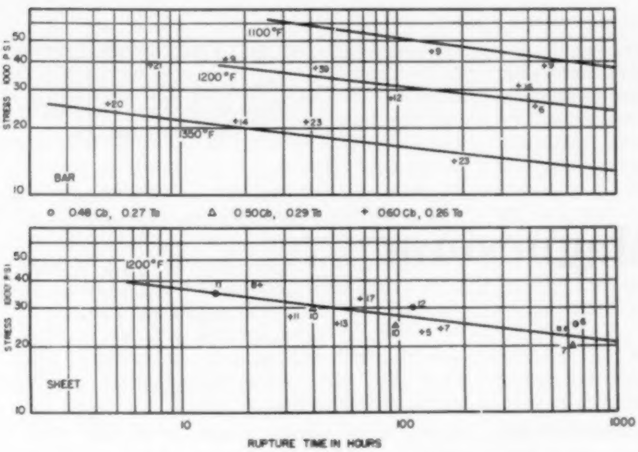

Fig. 10 — Stress-Rupture Data for 18-8 Steel Bars and Sheet Containing About 0.25% Ta and 0.50% Cb

tantalum, and on two normal 18-8 Cb steels. For these, standard tensile specimens 0.25 in. in diameter were machined from wrought ½-in. bars and were tested at 1100, 1200 and 1350° F. (593, 650 and 734° C.) after annealing for times up to 1 hr. at 1965° F. (1075° C.) and air cooling. (The variations in annealing time did not appear to have any influence on the properties of the steels.) In addition, standard sheet specimens 0.06-in. thick were tested at 1200° F. (650° C.); these specimens were heat treated 10 to 15 min. at 1965° F. and air cooled. Data for the normal 18-8Cb steels are plotted in Fig. 9; the numeral adjacent to each plotted point is the % elongation at fracture. The calculated rupture stresses for 100-hr. and 1000-hr. life are given in Table IV.

The data for the steels modified with tantalum are summarized in Fig. 9 and 10. The actual rupture curves in Fig. 14 and 15 represent the data for the normal 18-8 columbium steel and were presented for direct comparison with the tantalum-modified steels. The data points for the tantalum-bearing steels fall uniformly around the rupture curves for the normal 18-8 columbium steel, and it may be concluded that none of the modifications significantly affected hot strength. The hot ductility of the tantalum modified steels is also comparable to that of the normal steel. These results are in agreement with tests made on other high-temperature alloys which showed that tantalum could be substituted wholly or partially for columbium without detrimental effect.

Summary — Studies of 18-8 steels show that columbium may be replaced with an appropriate amount of tantalum when its higher molecular weight is taken into consideration. On an equivalent weight basis, tantalum is only half as effective as columbium in imparting practical immunity to intergranular attack. On this basis, a columbium-plus-tantalum content of at least ten times the carbon content should suffice.

On an equal weight basis, tantalum is as effective as columbium in promoting high-temperature strength, and therefore a partial replacement of columbium with tantalum in the 18-8 columbium Type 347 steel has no significant influence on hot strength and ductility. Similarly, the room temperature strength and ductility are not materially changed by the presence of like percentages of tantalum.

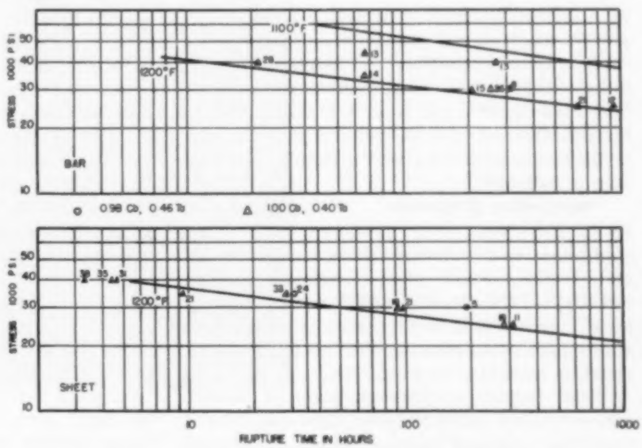

Fig. 11 — Stress-Rupture Data for 18-8 Steel Bars and Sheet Containing About 0.40% Ta and 1.0% Cb

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Sparking Magnesium

During the casting of magnesium, the ingot surface is occasionally coated with a black substance which sometimes has the remarkable property of flashing and burning when it is hit or scraped against another ingot. Not all of the black coating found on magnesium will flash, but in a few instances the action has been violent enough to be dangerous. For example, a flash from the core of a hollow magnesium ingot once projected a flame a distance of five to ten feet. The work which is summarized here was undertaken to find the causes of this unusual hazard.

Only one other kind of a sparking coating from commercial operations has come to my attention: Certain pieces after the conventional chrome-pickle have flashed when one piece was shoved over another soon after the treatment. The coating had a gray powdery appearance rather than the usual iridescent brass color left by a correct pickling. The active agent in this powder has been reported to be an intermetallic compound of magnesium and aluminum by W. S. Loose and H. K. DeLong in *Metal Progress* for May 1944 (p. 899) and in U. S. Patent 2,428,749 by H. K. DeLong. The phenomena are so similar in their manifestations that a definite relationship is indicated.

Occurrence of Exudate — The ingots referred to in this work were produced in a semi-continuous casting process known as the direct chill (D.C.) process, wherein water is sprayed directly on the freezing metal issuing from a mold. An essential feature, also, is a protective atmosphere of sulphur dioxide over the molten metal, to minimize burning.

The surface of such an ingot is usually covered with a rough textured, light colored and somewhat oxidized coating which is scalped from the ingot before it is fabricated (extruded, rolled or forged). Thick coatings of the *black* exudate are not found on commercially pure magnesium, although small spots or "blossoms" of black exudate may occur. The more highly alloyed ingots, and particularly those with a high aluminum content, are more apt to have a considerable amount of black exudate on their surfaces. It is usually found in marked longitudinal streaks, up to 1/8 in. thick, along the sides of the ingot, but it also occurs on the top and bottom surfaces. Minor additions of beryllium have been highly effective in preventing formation of exudate, both of the sparking and nonsparking varieties.

In one instance, a great deal of black exudate occurred on AM57S whose nominal composition is 6.5% aluminum, 1.0% zinc, and 0.2% manganese, balance magnesium. The metal was melted, refined by flux and cast as hollow ingots in a D.C. unit, during which time considerable burning was noticed on some ingots. The inner and outer surfaces of the ingots were exposed to air, sulphur dioxide, cooling water, and a mold grease. The ingots were later heat treated in an atmosphere containing sulphur dioxide. The exudate from this cast, which appeared both on the inner and outer surfaces of the ingots, will be referred to as Sample 1, and is shown in Fig. 1. The exudate of Sample 2 occurred on AMC57S ingots (which had the same nominal composition except for a lower iron content), cast and heat treated in a similar manner.

While a weak sparking has been reported for ingots before preheating, the exudates have been highly active only after heat treatment. Scalping of the ingot before preheating, which is a normal practice, is the recommended procedure to avoid this type of trouble.

Properties of Exudate

The exudate in the two cases discussed here gave off sparks when struck with an iron or aluminum rod, when scraped over another piece of metal, or when cut by a saw. Some large areas burned with extreme violence, although the ingot itself was not ignited. All of the exudate on a given ingot seemed equally active.

A white deposit (ash) remained, which smelled of sulphur dioxide.

Although the most striking demonstration of reactivity is the flashing on an ingot surface, a more sensitive test comes from heating a small quantity of the separated exudate. An active sample will flash near the melting point of the parent alloy; under similar circumstances dry magnesium powder, aluminum powder, or magnesium-aluminum compound ($Mg_{17}Al_{12}$) will burn quietly. Loose exudate placed on an iron anvil will flash when struck a sharp hammer blow. It can also be made to go off when hit with a hammer on an aluminum sheet, but this requires a considerably heavier blow. The flash in this percussion test is similar to that from metallic calcium.

The samples for analysis were scraped from the surface by sharp iron tools without accident when due precautions were taken to avoid generation of heat. The exudate was separated partially from adhering magnesium by suspending the ground mixture in a bromoform-carbon tetrachloride solution of density 2.0 g. per ml., wherein the exudate sank while metallic magnesium floated.

Microscopic examination at 40 diameters showed the exudate to be quite homogeneous and to have a spongy crystalline appearance. Its surface area* was 5 sq.m. per g. This happened to be about the same area as that of a sample of magnesium powder which burned quietly on heating. Thus, it seemed unreasonable to ascribe sparking merely to finely divided particles of metal.

Fig. 1 — Direct Chill Ingots of AM57S for Tubing, Partially Coated With Sparking Exudate. The active coating is black and the white areas have resulted from flashing the black material. Note the thick deposit of exudate on the inner surface of the hollow ingot at top right

Analyses — The beryllium content of all the ingots which produced exudate was less than 0.00005%. Comparative analyses of the metallic elements in the exudate and the parent metal have shown an enrichment of aluminum, zinc, calcium, boron, sodium, and potassium in the former. Magnesium was the major metallic constituent of the exudate, and it contained an appreciable quantity of sulphur, present largely as sulphate with a small amount of sulphide.

The exudate evolved gas when it was treated with water. It dissolved completely with much gas evolution in dilute hydrochloric acid. After flashing, the ash reacted with water to evolve about the same amount of hydrogen as it would before flashing, but very much less when dissolved in acid.

X-ray analysis of Sample 1 after some exposure to room air showed a large quantity of magnesium, a medium quantity of magnesium sulphate monohydrate, and a small quantity of

*Measured after evacuation at 25° C. or at 200° C. by a standard gas adsorption technique employing *n*-butane at 0° C., as described by S. Brunauer, P. Emmett and E. Teller in *Journal* of the American Chemical Society, Vol. 60, 1938, p. 309.

A black coating occasionally on magnesium ingots may spark and burn violently when hit or scraped against another ingot. The active agent has been identified as an intimate mixture of metal and sulphate, the latter being formed from sulphur dioxide atmosphere used to prevent burning of the magnesium. Although no serious production problems have been created by this phenomenon, its possible hazard warrants care on the part of casters and fabricators.

aluminum. Sample 2 showed a medium quantity of anhydrous magnesium sulphate, a medium quantity of $Mg_{17}Al_{12}(Mg_3Al_2)$, a small quantity of magnesium, and a questionable trace of magnesium oxide. (Sample 2 had less exposure to water vapor before the X-ray analysis, which presumably accounts for the magnesium sulphate being in an anhydrous form.)

Weight loss for Sample 2 on heating in vacuum for 1 hr. at 135° C. was 0.7%, and 0.0% additional loss on heating at 450° C. for 1 hr. The negligible loss between 135 and 450° C. gives additional evidence against the presence of a hydrate in this material. The loss on ignition of Sample 1 was 1.9% at 135° C.

Sample 2 was extracted with dry ether (in which aluminum hydride would be soluble); the extract evolved hydrogen equivalent to no more than 0.07% AlH_3 in the original powder. This result also argues against the presence of MgH_2, since many hydrides are soluble in ether and any material of only slight solubility would have been extracted and found under the condition of the test.

One of the most striking characteristics of the exudate is its ability to flash in vacuum (that is to say, continuous evacuation to <0.01 mm. Hg) or in an argon atmosphere. This result argues strongly against the supposition that the phenomenon may be caused by water evolved from a hydrate. The gas evolved when Sample 2 flashed in a vacuum was very small.

The data are consistent with the following composition of this exudate Sample 2: 42.3% $MgSO_4$, 19.7% MgO, 19.3% $Mg_{17}Al_{12}$, 9.8% Mg, 2.7% MgS, 1.2% CaO, 1.0% Mg_3N_2, 1.0% Zn, 0.7% MgC_2, 0.7% loss on ignition, 0.5% Mn_2O_3, and 0.2% SiO_2. This comes to a total of 99.1%. A similar rationalization can be made of an analysis for Sample 1 if it is assumed that somewhat more water was present in hydrated compounds.

Synthetic Mixtures

Mixtures of magnesium powder and magnesium sulphate, ground together and heated in a porcelain crucible, were found to flash much like the exudate; maximum activity was found at a mole ratio of about 3.5. Aluminum sulphate acted even more violently, and a series of other sulphates, nitrates, and oxygen-containing chemicals gave the flashing phenomenon. Other highly active ones, of those tested, were ammonium sulphate, barium nitrate and hydrated ferric nitrate. These artificial mixtures of compounds with magnesium metal powder also were sensitive to percussion, the most brisant, again, being the mixture of anhydrous aluminum sulphate and magnesium.

Repetition of these experiments with aluminum powder showed the same general characteristic, although the flashes were milder. This action recalls explosions that have resulted from molten aluminum and the sulphates of sodium, recorded by E. J. Kohlmeyer in *Aluminium*, Vol. 24, 1942, p. 361, and potassium sulphate, barium sulphate, or calcium sulphate, as noted by Mellor in his "Comprehensive Treatise in Inorganic and Theoretical Chemistry", 1924 Edition, Vol. 5, p. 218.

Effect of Water — The magnesium exudate will largely lose its sensitivity to percussion after it has been immersed in water, moistened with water, or exposed to moist air. It would seem that immersion would leach out much of the sulphate. The effect of moist air may be to hydrate the sulphate and to oxidize the finely divided metal surfaces and make them unavailable for rapid reaction. The exudate from Sample 1 (which was not percussion-sensitive after long standing) did flash when the ingots were remelted. The hydrated magnesium sulphate had lower sensitivity to percussion when mixed with magnesium powder than did the anhydrous salt, but both flashed to the same extent when they were heated.

Nature of Exudate on Ingots

All of the foregoing seems to point to a mixture of magnesium alloy and magnesium sulphate as being responsible for the percussion sensitivity and flashing of the black exudate. In this mixture the sulphate must act as an oxidizing agent. On this supposition the following equation shows a possible situation:

$$MgSO_4 + 4Mg \rightarrow 4MgO + MgS$$

There is little question but that sparking material is from a low-melting constituent exuded during casting. (The excess of aluminum, zinc, and calcium noted in the analysis may lower its melting point.) This material must react with sulphur dioxide and oxygen in the ambient atmosphere to form the magnesium sulphate. While this process may go to some extent at the casting unit, it seems to be advanced most rapidly during the preheating of the ingot for homogenization. Apparently the normal heat treating furnace atmospheres contain sulphur trioxide in addition to sulphur dioxide; this is suggested by the iron sulphate which forms on the steel racks which hold the magnesium. The fact that the active exudate has only been observed for alloys containing moderately high aluminum may result either from the high reactivity of the magnesium-aluminum constituent or from the longer solidification range of these alloys.

Allen S. Russell

Now assistant chief of the physical chemistry division of Aluminum Research Laboratories, a position he has held since 1945, his principal fields of interest are the properties of alumina, the separation of aluminum from its ores, ion scattering and catalysis. His interest in safety measures brought his attention to the problem of "sparking" magnesium. Mr. Russell was born in Bedford, Pa., in 1915 and educated at Pennsylvania State College, receiving his doctorate in 1941.

Active Product of Dichromate Pickling

Magnesium alloy products are frequently subjected to a chrome-pickle treatment (dichromate dip) to minimize corrosion and to furnish a base for paint. As was mentioned in the introduction, this treatment may lead to an easily recognized gray coating which can flash on abrasion. Experience indicates that even commodities having readily visible amounts of gray powder on the surface lose their tendency to spark on exposure to the atmosphere.

Chemical analysis of the powder on AM58S (8.5% aluminum, 0.5% zinc, 0.2% manganese, balance magnesium) extrusions, which flashed readily after treatment by an improper modification of the conventional chrome-pickle (American Magnesium Corp.'s treatment A), showed a high concentration of chromium (presumably chromate or dichromate) and nitrate.

This spark-emitting coating could be produced on a laboratory scale by dipping similar magnesium sheet in a mixture of concentrated nitric acid and sodium chromate. While no extensive survey of these coatings has been attempted, it is reasonable to suppose that dichromate or nitrate may usually be present in these coatings and that this, in intimate mixture with magnesium-aluminum constituent, leads to the sparking.

Safety Considerations

These tests emphasize the precautions that must be taken under certain conditions of processing if accidents are to be prevented in the handling of magnesium alloys in production.

The agents which are capable of sparking violent flashes on magnesium surfaces are ordinarily not thought of as hazardous. It also seems remarkable that intimate mixtures of finely divided magnesium alloy with these oxidizing agents are formed under commercial conditions. Nonetheless, this can and does occur, and the dangers therefrom can be very real to unwary workmen.

Particular care should be employed when using a sulphur dioxide atmosphere for heat treating any *new* or unfamiliar types of magnesium alloys. Also, the metallurgist should observe carefully lest changes in the operating conditions from those which have been established by long practice should cause unexpected trouble.

No sparking black exudate has ever been observed on the surface of magnesium ingots containing beryllium as described in U. S. patent 2,380,200 issued to P. T. Stroup and George F. Sager.

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Bright Hardening, Carburizing and Carbonitriding

DEVELOPMENT of controlled atmosphere heat treatment has undoubtedly been the outstanding accomplishment of recent years in the metallurgical field. Many types of atmospheres and generator equipment are now available for industrial use, covering a wide range of processing. The advantages and limitations of each type are now generally realized. Some are intended primarily to prevent oxidation, others to promote a surface reaction, but in all the direct result is clean work. Its favorable influence on costs has resulted in such a marked industrial interest that recent developments in furnace design have been in the direction of control of cleanliness.

Heat treating, as exemplified by the hand-fired forge, provided no control over surface phenomena. It was not until the 20th century that some attempt at controlling gas-fired furnaces was made, by adjusting the air-fuel ratios of the burners, with the idea of reducing the amount of scaling. About this time industrial requirements led to the adoption of pack methods, where charcoal or cast iron chips were placed with the work inside fairly tight boxes to prevent oxidation, and pack carburizing and salt baths for imparting wear resistant surface layers to the work. Although satisfactory in most respects, these methods provide only limited control of surface characteristics.

Prior to the last war, some metallurgists were using gas atmospheres to prevent oxidation, but relatively little work had been done with highly "reducing" gas mixtures. War production requirements necessitated more suitable equipment, and the furnace manufacturers concentrated on this phase of design. Favorable acceptance and the increasing demand for units of this type give tribute to the success of these early installations.

Theory and Practice — In general, two conditions influence the surface appearance of the work — soot and discoloration (thin oxide). Sooting is of concern primarily in gas carburizing (and related operations when using an atmosphere of high carbon potential).

For many years heat treaters have endured soot and carbon film on carburized parts. With the advent of gas carburizing, interest was centered on obtaining an atmosphere with high carbon potential, and little attention was focused on the deleterious effects of sooting. Gradually, through attention to the laws of gas chemistry, and the use of a diluting or "carrier" gas produced by catalytic combustion of a hydrocarbon gas, this condition generally improved. We can now furnish cases with any carbon-depth characteristic through proper gas flow control and with no excess sooting.

Most installations use a proportioned mixture of gases, consisting of a carrier gas manufactured in a special gas producer or generator and of hydrocarbon additives. (For carbonitriding, varied concentrations of ammonia are also added.) The carrier gas is usually a product of catalytic reaction of air and fuel gas; the proportions (degree of combustion) determine the gaseous constituents. The products of combustion consist of CO_2, CO, H_2, N_2, CH_4 and H_2O. The CO_2 and water vapor are considered highly oxidizing to steel and must be controlled. With an endothermic reactor — requiring outside energy to sustain partial combustion (approximately 25%) — the amounts of CO_2 and H_2O are negligible, but in an exothermic reaction the

percentages are sufficiently high to require their removal. Methane, CH_4, and carbon monoxide, CO, are "reducing" gases in contact with hot iron oxide, and under normal operating conditions are present in sufficiently large amounts to counteract, chemically, the effect of small amounts of CO_2 and H_2O remaining in the carrier gas. Hydrogen is slightly decarburizing to hot steel, but this action is minimized by nitrogen dilution or CH_4 concentration.

In carburizing it is general operating policy to control the generator gas to a relatively inert or lean mixture in respect to its reaction with the work and, as stated above, to add proper amounts of hydrocarbon gas for carbon control — to avoid decarburization or to carburize, as the case may be. The dew point of the generator gas affords an indication for regulating the carbon potential of the gas, and can be used to adjust equilibrium in carbon restoration or clean hardening of medium carbon steels. If rich ratios of the gas-air are fed to the generator, it often results in sooting of the catalyst, and a burn-off period is required to restore proper operating conditions.

Although dependent on gas flows, the condition of the atmosphere *at the work* regulates the surface characteristics that are produced. Accurate gas analyses are extremely difficult to obtain, due to the constant gas reactions as equilibrium changes at various temperatures. Equilibrium at any given temperature, wherein the atmosphere becomes neutral with respect to the work, is directly related to the ratios of CO/CO_2 and H_2/H_2O; by varying these ratios the atmosphere becomes oxidizing or deoxidizing, carburizing or decarburizing.

Sooting Conditions

Considered individually, the CO/CO_2 ratio is related directly to the deposition of soot. An excessively high ratio of the partial pressures of CO and CO_2 at any given temperature favors sooting. It seems as though CO becomes increasingly stable at higher temperatures, so this sooting tendency decreases with temperature — other things being equal. At the lower temperatures the decomposition *rate* is slower and this tends to counteract the decrease in stability of CO so that the work remains relatively soot free if cooled in an atmosphere that is nonsooting at heat treating temperatures.

High methane concentrations also have a bearing on the deposition of soot but — in contrast with CO — it is increasingly unstable at higher temperatures and decomposes readily with an increase in temperature. Hydrogen, in appreciable amounts, tends to counteract this.

We have found, as a practical matter, that regulation of gas flows aids in combating soot. If the enrichment gas is not added to the carrier gas until the work reaches approximately 1450° F., the hazard of sooting is reduced. This seems reasonable to expect, as carbon absorption is negligible until there is some austenite at the steel surface (approximately 1350° F.) and we might expect carbon to build up on the surface prior to this time. Initial penetration is very rapid after this temperature is reached; then the carbon gradient is reduced by inward diffusion, and the speed of absorption drops. Under these conditions, we would expect that a lower amount of enrichment gas would also be advisable during the latter portion of the soaking period. As the operating temperature is increased, carbon penetration is proportionally increased and the susceptibility to sooting lessened. Under favorable conditions, this fact has been confirmed.

It can be easily understood that sooting is primarily dependent on proper operating conditions and is not a function of furnace design. Discoloration, on the other hand, can usually be attributed to oxygen, water vapor or some type of lubricant used in prior fabrication of the part. Actually two stages of oxidation must be considered — one occurring at high and one at low temperatures. High-temperature oxidation is of little consequence when dealing with protective atmospheres — especially those used in carburizing — as the gas is of a highly reducing nature. On the other hand, an atmosphere such as dissociated ammonia (hydrogen plus nitrogen), which is commonly used in bright annealing, brazing and hardening, is readily susceptible to contamination, unless traces of water vapor are removed from it. Although rarely oxidizing to the extent of producing a loose scale, there is generally danger of decarburization.

Data published on the effect of temperature indicate that higher CO/CO_2 ratios are required for equilibrium with steel of a given carbon content as the temperature of the work is increased. Therefore, there is less tendency for decarburization during the heating or cooling cycle, due to the decreased equilibrium requirements. The converse is true of the H_2/H_2O relationship; as the oxidation tendency varies inversely as the temperature, work may be clean at high temperatures, but will stain during cooling. An increase in the H_2/H_2O ratio will correct this. It can be easily understood why O_2 and H_2O must be very low during cooling. Even an instantaneous exposure to contaminated

atmospheres during a quench is sufficient to discolor the work.

It is impossible to exclude oxygen entirely from the furnace. Air seepage will occur. Design features, at best, can only minimize this; a reducing atmosphere must be present to counteract it immediately. Ammonia additions (as used in carbonitriding) are beneficial, as they furnish additional hydrogen to replace any lost by the formation of H_2O with infiltering air.

Air or water in the quenching oil can also cause discoloration. Water leakage (normally from the cooling system) can be detected quite readily by visual examination. The oil is characterized by a brownish-red color — but only when an appreciable amount of water is present. Boiling the oil removes all traces of water and generally makes it suitable for reuse.

Table I — Common Steels Bright Hardened

Material	Treatment	Temp. °F.	Gas Flow			Dew Point*	Remarks
			Gen.	Natural	NH_3		
4140	Harden	1500	250	—	—	+40	Light gray
1117	Carbonitride	1600	250	15	30	+15	Bright
Type 310†	Anneal	1800	250	—	—	0	Discolored
8620	Carburize	1700	250	15	—	+10	Bright‡
1045	Harden	1550	250	—	—	+40	Bright
1345	Harden	1550	250	—	—	+40	Bright
1141	Harden	1550	250	—	—	+40	Bright
1018	Carbonitride	1500	250	15	30	+15	Bright

*Dew point of generator gas.
†25-20 stainless steel, oil quenched after annealing.
‡Very slight grayish discoloration.

Moisture in oil due to condensation is usually more troublesome. The concentration is too little for visual identification, and it produces only a partial discoloration of the work as characterized by a dull, gray finish. This condition is especially noticeable during intermittent operation on humid days.

Oil contaminated with air is usually more common, but has less effect on discoloration. Many furnace installations use the quenching oil as an air seal, but air can easily infilter through it. Foaming of the oil indicates air entrapment. There has been some indication that (under unfavorable conditions) discoloration from this source is more pronounced on the heavier sections, due to their slower cooling rate. After extended week-end shutdowns or with new oil, work does not immediately come out bright, but one or two dummy runs will remove the entrapped air and the oil is then conditioned for bright work.

In atmosphere cooling, care must be taken lest the work leaves the cooling chamber too hot. A maximum temperature of 325° F. has been accepted as a requisite for bright work. Even then, slight discolorations have been noted at the tray contact areas. Whether this is due to oxidizing gases entrapped at such places, or to a slower cooling rate of the more massive tray, has not been determined.

The condition of the parts prior to heat treatment must be considered. Pre-treatment cleaning or degreasing depends on the type of coating, on the surface condition, on subsequent operations and, of course, on the furnace equipment. High-sulphur cutting oils are notoriously detrimental to bright work, but any oil or residue which is highly volatile will usually have little effect. The main objection is the smoke and sooting during burn-off immediately after charging the oily parts. This condition may be minimized by increasing the generator gas flow to purge the heating chamber more quickly.

Oxide coatings are readily reduced in a correct furnace atmosphere. Badly rusted pieces clean up satisfactorily. For example, clutch levers which were preheated at 1000° F. in a draw furnace acquired a light scale and bad discoloration, but all evidence of this condition was eliminated during the carbonitriding cycle. Parts reheated after pack carburizing and slow cooling regain their original bright finish.

"No-carb" pastes and other stop-off coatings used for selective carburizing remain unchanged and must be removed after the heat treatment. Copper plate or plugs on area to be kept soft remain untarnished. (When plugs are used in carbonitriding, the case of carbon and nitrogen is not eliminated, but — due to retardation of the cooling rate by the copper mass — the area under the plug remains soft and the surface color remains unchanged.)

Alloying elements affect the degree of brightness of bright treated steel parts. Generally, straight carbon steels acquire the most satisfactory finish. A group of steels in common use are listed in Table I. All low-carbon grades were carbonitrided while the medium-carbon grades were clean hardened. An endothermic generator gas, which was used in this instance,

is notoriously incapable of bright hardening stainless steels, due to its high chromium contents. The discoloration noted on two of the above samples may also be attributed to this effect. S.A.E. 4140 steel, which contains in the neighborhood of 1% chromium, has a light gray luster. Any increase in chromium above this content results in increasingly darker hues, and steels containing an appreciable percentage of any of the carbide-forming elements would be expected to react similarly with an atmosphere of high carbon potential. Another of the variables in the above samples, nickel, has no bearing on brightness; sample parts containing as high as 80% Ni retain their bright luster. High manganese contents, as characterized by "Man-Ten", revealed no harmful effect. Slight variations in finish on other parts are attributable to corresponding variations in gas flows.

Equipment

With a few of these limitations in mind, we should briefly review the desirable features that must be incorporated in a furnace for producing bright work. It is obvious that the unit must be gastight and the work protected from oxidation through the heating and cooling cycles. This can be accomplished only by positively sealing off the heating chamber and cooling unit from outside air. In this respect a batch-type unit is more practical than a continuous furnace; once the atmosphere has reached equilibrium conditions in the former, the chamber remains sealed from further contamination until the cooling or quenching cycle is completed. Combustion gas must be segregated from the atmosphere through the application of radiant tube or full muffle-type construction. (Contamination precautions are unnecessary in electrically heated units.) A gastight frame entails as much welded construction as possible, and any necessary openings other than the doors should be completely gasketed or sealed. The door areas are the chief source of air contamination and are necessarily of minimum dimensions. Flat, ground door frames and door plates minimize leakage. A flame curtain must be provided at the discharge end as a precaution against explosion, but is not a requisite at the charging door, since the heating chamber is completely purged by the time the work has reached oxidizing temperatures.

Continuous furnaces employ vestibules or purging chambers at the charge and discharge ends to minimize air contamination after each push cycle. Sufficient time is allowed for purging these chambers before opening the inner doors for charging or discharging. As these inner doors are not gastight, contamination of the atmosphere in the heating chamber cannot be avoided, and their extensive length and large surface area offers additional possibilities for leakage.

A batch-type furnace containing many of the above features is shown in Fig. 1. It is adaptable for operations in the range of 1250 to 1850° F. requiring either cooling in an atmosphere or oil quenching. It was designed specifically to produce a bright finish, even on heavy

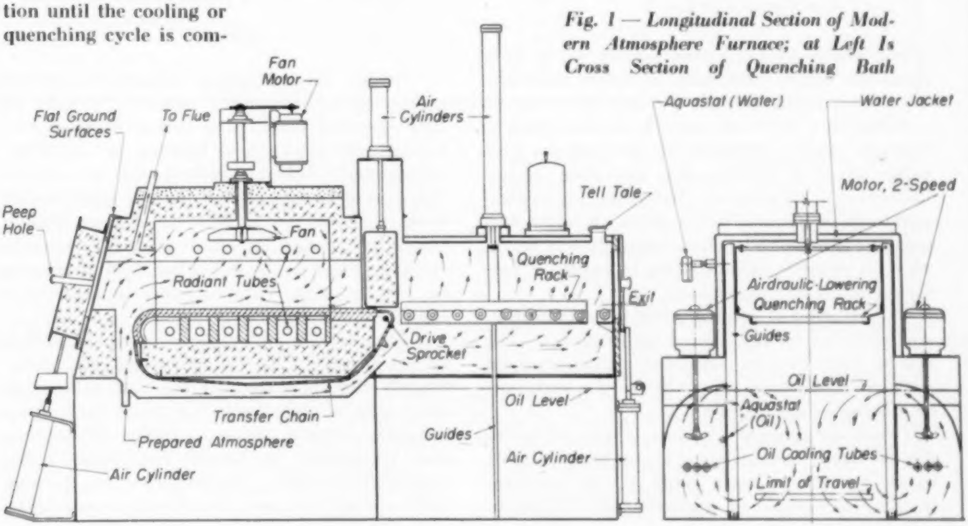

Fig. 1 — Longitudinal Section of Modern Atmosphere Furnace; at Left Is Cross Section of Quenching Bath

cross sections such as splined shafts, $1\frac{3}{4}$ in. diameter by 12 in. long.

This heat treating unit consists of a heating zone, water-jacketed cooling chamber, and quench tank. The furnace has a chain hearth, recirculating fan, and pneumatically operated front and rear doors. It provides for completely automatic operation through any predetermined cycle, with electric timers and selector switches in a circuit controlled by a single start button. The unit is suitable for normalizing, annealing, stress relieving, carburizing, carbonitriding, and furnace brazing in conjunction with atmosphere cooling; and for bright hardening, carburizing and carbonitriding when oil quenching is desirable.

Oil agitation (the term "agitation" is used erroneously — it is a flow) is provided by motor-driven propellers mounted on either side of the quench. In this manner, the oil is drawn under the baffles, passed over a series of finned cooling coils, and forced down through the work. Positive circulation quenches small, light parts

Exact duplication in hardening is possible as the transfer period from heating zone to the quench is always equal, and the oil temperature and its rate of flow can be held constant from load to load.

A few typical carbonitriding treatments run in one of these units are outlined in Table II, which vary in respect to gas flows and temperature. Corresponding analyses of the furnace atmospheres are also noted. The carrier gas, resulting from an air-gas ratio of 2.42 to 1.00, analyzed 0.2% CO_2, 21.4% CO, 0.9% CH_4 and 34.0% H_2, and had a dew point of +20° F. We have found that bright work may be expected within the range of operating conditions listed in this table. Carbon penetration was measured from stepdown bars, machined from C-1018 steel and processed 60 min. at temperature. Sample cuts were made in 0.002-in. steps to a depth of 0.010 in. and a final cut of 0.005 in. removed, totaling 0.015 in. The reader will note the wide range in surface carbon can be attained by varying the enrichment gas flow and the temperature.

Table II — Typical Carbonitriding Runs on C-1018 Steel

Temperature	Gas Flow			Dew Point*	Gas Analysis				Carbon Content at Depth Stated					
	Generator	Natural Gas	NH_3		CO_2	CO	CH_4	H_2	0.001	0.003	0.005	0.007	0.009	0.012
1600° F.	250	0	30	+20	0.6	18.0	0.24	35.7	0.32	0.29	0.27	0.25	0.22	0.21
1600	250	15	30	+18	0.3	18.2	2.8	35.4	1.21	0.90	0.85	0.78	0.71	0.63
1600	250	30	30	+18	0.1	17.5	4.4	35.4	1.34	1.09	0.96	0.90	0.80	0.71
1500	250	15	30	+20	0.3	17.8	2.6	36.3	1.39	0.85	0.78	0.70	0.61	0.45
1700	250	15	30	+20	0.2	17.9	1.8	37.3	1.33	1.11	1.08	1.02	0.97	0.91

*Of generator gas, °F.

which might otherwise tend to float out of their container under conditions of severe agitation. Two oil impellers enable the operator to select a drastic or a moderate quench, or something in between, readily adaptable for processing a wide range of steel grades, and providing proper hardness. Cracking or distortion on critical parts can be avoided by choosing an initial fast quench. Furthermore, high-speed flow is necessary on densely packed loads to assure a uniform cooling rate throughout.

Circulation of cooling water is controlled by aquastats, set for the desired temperatures. The system may also be insulated and contain an immersion heater to supply hot oil for such hot-quenching as martempering.

Such an automatic system is well suited to the stringent metallurgical requirements of today, for it eliminates many of the variables common to manual or semiautomatic operation.

Costs

In the present highly competitive market, management is primarily interested in reducing unit operating costs. The savings through controlled atmosphere heat treating are generally appreciated. Actual operating costs are more a function of furnace design than of heat treating process. Often, the greatest savings are realized indirectly through the elimination of processing methods prior to or following heat treatment. In this respect, cleaning operations deserve especial attention.

The obvious advantage of clean hardening is the reduction in subsequent cleaning costs. Usually the application of the part determines the degree of cleanliness required. Aside from consumer appeal, many specific applications lend themselves to special consideration for absolute cleanliness. In such instances, cleaning costs are so high and cleanliness so restrictive

that the original production of bright work saves much money. This is possibly best exemplified in parts that must be electroplated. One manufacturer formerly processed millions of small parts yearly in liquid cyanide baths. Following this, all the parts required plating, and stringent care was mandatory in cleaning; each part had to be handled individually. Cost analysis revealed that about 12¢ per lb. was spent on cleaning prior to plating! After installing bright carbonitriding equipment, the entire cleaning department was eliminated. In addition, normal heat treating costs were only 25% those of liquid cyaniding.

Many plants now use acid for cleaning, and there is always danger of hydrogen embrittlement. This hazard was eliminated by bright hardening various types of highly stressed springs, otherwise subject to failure from acid embrittlement.

Although hardened parts are almost universally shotblasted, many with small bores, internal threads, and irregular indentations cannot be cleaned satisfactorily in standard equipment. Such parts often require special grits and extra care in handling. Liquid blasting is sometimes suitable, but often requires hand-directed blasts for individual cleaning. Hardened parts, with thin, sharp edges and corners, must be handled carefully to prevent breakage. On parts such as these, there is no doubt of the practical aspect of bright hardening.

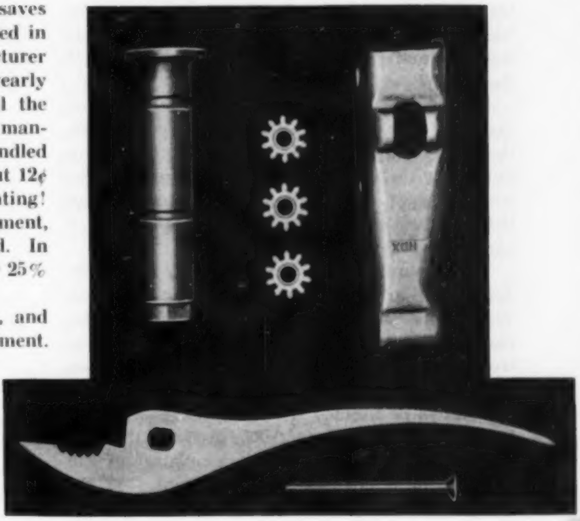

Table III — Auxiliary Savings Through Clean Hardening the Parts Shown Above

Part:	Valve	Plier Segment	Gear	Lever
Material	C-1020 butt-welded to C-1045	C-1060	C-1020	C-1010
Previous heat treatment	Forced convection draw	Clean harden in salt	Cyanided	Carburized
Present bright treatment	Stress relieve and harden	Harden	Carbonitride	Carbonitride
Process eliminated	Retapping threaded hole	Finish grind	Cleaning before plating	Blasting
Previous unit heat treating cost	$0.0005	$0.005	$0.001	$0.0015
Present unit heat treating cost	0.0007	0.0007	0.00025	0.0011
Unit cost eliminated	0.032	0.030	0.001	0.015
Unit savings	0.0318	0.0343	0.00175	0.0154
Ratio of savings to cost of heat treatment	45 to 1	49 to 1	7 to 1	14 to 1

Due to the unusual interest in carbonitriding, combined treatments may be devised. For instance, two parts can be silver brazed and carbonitrided in the same operation. Requisites of this treatment are protection of the solder from oxidation and preparation of perfectly clean contact surfaces for proper bonding action. Availability of solders whose melting points correspond to the required carbonitrided temperature ranges simplifies the operation.

In addition to some of the examples noted above, other indirect factors do not necessarily appear on cost records as savings. Reduction in intershop handling and transportation costs, savings in machine setup time by combination of operations, and production speed-up — all must be considered. For example, since furnace sooting must be more carefully controlled when bright hardening, less downtime is required for burn-out of catalyst. (Tray burn-off is required in relatively few instances.)

A few practical examples of cost savings in associated operations are shown in Table III.

On one of the parts improved physical properties were attained and, as in so many instances, this improvement in quality overshadows in itself the importance of savings in process.

Of course, the cost of bright hardened or annealed work is dependent on the equipment, the process, and the parts themselves. The more automatic the equipment, the lower usually the cost. Deeper cases require longer soaks, and the addition of ammonia increases the cost of carbonitriding over carburizing.

In general, costs vary from ¼¢ a lb. up, depending on burden and accounting practices. Total costs, which include (besides labor, material, upkeep) factory overhead and administrative expenses, will generally range upward from ½¢ a lb. Details for a clutch plate weighing 8 oz. made of rimmed steel, bright carbonitrided to a depth of 0.003 to 0.005 in. are tabulated below. The furnace handled one charge of 250 lb. each hour. Heat treatment was at 1550° F.; the work was at heat 10 min., held in the cooling zone above the oil for 5 min. (the cooling jacket shown in Fig. 1 being at 130° F.), quenched 2 min. in oil at 150° F. Case was file hard.

The generator gas (dew point +15° F.) was supplied at the rate of 250 cu.ft. per hr., with 15 cu.ft. natural gas and 25 cu.ft. ammonia added. Details of cost follow:

1. Direct Labor		$0.25
2. Treating Materials		0.12
3. Factory Overhead in Detail		
(a) Fuel — Electric	$0.01	
Gas	0.15	
(b) Maintenance (on equipment)	0.10	
(c) Depreciation and amortization on equipment	0.15	
(d) Insurance on equipment	0.04	
(e) Taxes on equipment	0.04	
(f) Occupancy — building	0.02	
(g) General factory	0.05	
(h) Supervision	0.04	
Total factory overhead		0.60
Cost of work produced		0.97
4. General and Administrative		0.15
Total Operating Cost per Furnace Hour*		$1.12
Cost per pound		$0.0045
Cost per piece		$0.0022

*Does not include outside work, royalties, inspection, laboratory expense, order and service department expense, receiving and shipping expense.

High Machinability and Productivity of Ductile Iron*

INCREASED PRODUCTIVITY in machining means not only more pieces per hour but also a reduction in floor space and capital investment, as well as increased manpower efficiency.

Long experience with conventional malleable iron, both long cycle and short cycle annealed, is ample evidence that highest machinability is obtained in irons having a ferritic matrix. The conventional gray irons can be annealed into such a ferritic structure, but then have little strength and hence find limited applications. Ductile iron,* however, either as-cast or annealed, maintains high physical strength and acquires excellent machinability.

Ductile iron is available in a variety of conditions. Three grades are suggested for general usage, namely 90-65-2, 80-60-5, and 60-45-15. These code numbers refer to tensile strength in 1000 psi., yield strength in 1000 psi., and per cent elongation in 2 in. on the standard A.S.T.M. 0.505 in. tensile test specimen. (See A. P. Gagnebin, *The Iron Age*, May 4, 1950.)

Attention was first directed to the high tensile strength properties shown by this material compared to the conventional cast irons; how-

*EDITOR'S FOOTNOTE: The meaning of "ductile iron" in this article is restricted to "magnesium-containing cast iron in which the free graphite takes the spheroidal form in the as-cast state". For other varieties see *Metal Progress* for November 1950, p. 729.

ever, interest is now turning to the 60-45-15 grade which combines good physical properties with excellent machinability, as will be presently described. This tensile strength, incidentally, is as high as the best grade of cast iron, determined by the 1.2-in. "arbitration bar", but in addition, the ductile iron offers a yield strength of 45,000 psi. minimum (0.2% offset or 0.5% extension by dividers) and a ductility of 15%, the latter two properties being practically absent in ordinary cast irons.

Cast steel, although possessing physical properties comparable to ductile iron, does not offer the advantages of simplified casting techniques and ease of machining

Microstructure

As is well known, gray irons are structurally characterized by the presence of free graphite in the flake form. The matrix structure generally consists of pearlite or free ferrite. High strength alloy irons may have an acicular structure. Usually, the matrix of gray irons contains coarse or fine pearlite, depending upon the cooling rate. Free ferrite is ordinarily present in small quantities in the as-cast condition; however, large amounts can be produced by annealing. (See the micros in Fig. 1, p. 240.)

Ductile irons, in contradistinction, are characterized by the presence of free graphite in the spherical form. The matrix structure, again, may be pearlite or ferrite or combinations of both. Ductile iron has been cast with matrix completely pearlitic or completely ferritic. It is possible also to anneal the pearlitic structures and transform all or part of it into free ferrite and graphite. The free graphite in ductile iron is described as spherical, while that of malleable iron is more accurately described as nodular. Representative microstructures, shown in Fig. 2, are of the materials on which the machinability tests were run. Compositions, physical properties, and heat treatments of those four flake-graphite irons and the five spheroidal-graphite irons are given in Tables I and II.

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Tool Life

Turning tests were made on bars 3 in. in diameter by 30 in. long in which the structure was very carefully controlled. Carbide tools were employed and cuts were taken 0.100 in. deep at 0.010 in. feed per revolution. The tool life test was ended when the wear land behind the major cutting edge reached 0.030 in.

The tool life results for the flake graphite test of cast irons are shown in Fig. 1, wherein tool life in terms of volume of metal removed is plotted against cutting speed. For a reasonable tool life of 200 cu.in. the acicular structure (curve at extreme left) would have to be cut at a speed of 150 ft. per min., the fine and coarse pearlite structures (which differ very little) at about 300 ft. per min., while the annealed ferritic structures (at extreme right) could be machined at about 950 ft. per min.

Tool life curves for the ductile cast irons are shown in Fig. 2. It is observed that machinability improves as the ductility increases, as the amount of free ferrite increases, or as the associated Brinell hardness decreases. Of particular significance is the fact that the annealed irons can be cut at speeds as high as 1000 ft. per min. with reasonable tool life. Incidentally, the end points in Fig. 1 and 2 represent a tool life of at least 1 hr.

When Fig. 1 and 2 are superimposed so a comparison can be made between the machining properties of the gray and ductile cast irons, it will be observed that the materials with 100% ferrite matrix, plotted at extreme right in Fig. 1 and 2, are practically identical. However, the

Table I — Cast Irons for Machinability Study

Mark	Structure	C	Mn	P	S	Si	Ni	Mg
	Flake Graphite Cast Iron							
Acicular, 263	Acicular iron	2.78	1.03	0.12	0.064	2.30	2.11	0.32 Mo
Fine, 225	Fine pearlite	3.22	0.62	0.08	0.097	2.10	0.85	0.64 Cr
Coarse, 195	Coarse pearlite	3.17	1.10	0.10	0.108	2.44	—	—
Ferrite, 100	Ferrite (annealed*)	3.47	0.35	0.05	0.133	1.62	—	—
	Spheroidal Graphite Cast Iron							
2%, 265	20% ferrite (as-cast)	3.33	0.45	0.11	0.018	2.66	1.65	0.078
4%, 215	60% ferrite (as-cast)	3.41	0.42	0.09	0.014	2.82	0.81	0.073
17%, 207	60% ferrite (as-cast)	3.82	0.23	0.082	0.018	3.04	1.13	0.082
20%, 183	97% ferrite*	2.79	0.53	0.09	0.014	2.76	1.59	0.071
22%, 170	100% ferrite*	3.69	0.27	0.045	0.014	2.64	1.15	0.060

*Annealing cycle: Heated to 1650° F. for 30 min., furnace cooled to 1275° F. and held there for 5 hr., air cooled.

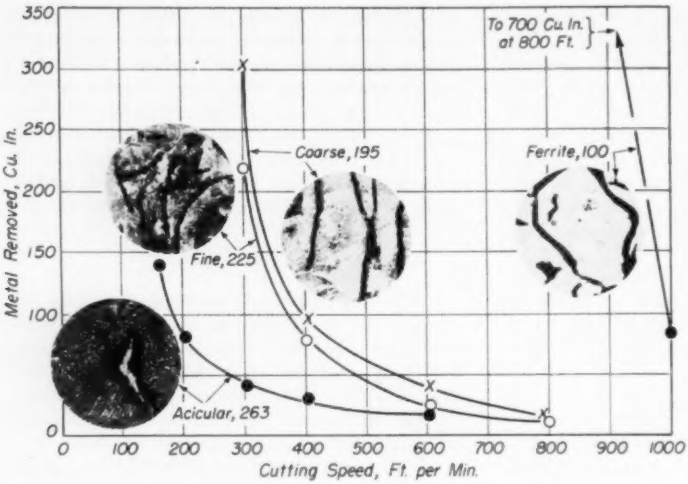

Fig. 1 — Machinability Tests on Cast Irons Containing Flake Graphite. Structure and Brinell hardness noted for each variety. Tool life measured by wear land behind cutting edge; test stopped when this reached 0.030 in.

ductile irons are about 25% more machinable than the flake graphite irons at the same hardness level. For example, tool life for 200-cu.in. duty can be achieved at 200 ft. per min. with ductile iron marked "2%, 265", but the speed must be slowed down to 150 ft. per min. for the flake graphite iron "acicular, 263". Likewise the cutting speed (using the same criterion) for ductile iron "17%, 207" is 420 ft. per min., and only 325 ft. per min. for coarse pearlitic iron with 195 Brinell hardness. Table III summarizes such a comparison for all nine irons tested.

Again, particular attention should be paid to the fact that by producing a completely ferritic structure through annealing or other means, machinability of the irons is tremendously improved. Ductile irons in such condition still retain high physical strength; in fact, the strength of the completely annealed ferritic iron was greater than the highest strength as-cast gray iron, 70,000 vs. 59,700 psi. Thus, the ferritic ductile iron not only provides high strength, but also high ductility which is completely lacking in gray iron. At the same time, the ferritic ductile irons can be machined at much higher speeds than the best of the commercial gray irons, and hence provide material for high production rates.

Ductile irons are now being used primarily for high-strength parts; however, it appears logical to anticipate the use of large quantities in the ferritic form for applications where high machinability is the ruling consideration, because it is possible to combine (along with high strength) cutting speeds and production rates far greater than those possible with gray iron.

Annealing

Most of the ductile irons cast in large quantities to date show a spheroidal graphite in a matrix containing a percentage of pearlite varying from 50 to 100%. These structures are responsible for high strengths but, as previously pointed out, are not the most desirable from a machinability standpoint.

The desirable annealing practices that have been recommended involve a holding time of 30 to 60 min. at temperatures of from 1600 to 1750° F., followed by a 5-hr. treatment at 1275° F. These cycles almost always have been extremely liberal — on the safe side — and high-production operations justify a careful evaluation of the cycle to be used.

The treatment at 1600 to 1750° F. has as its objective the rapid decomposition of any den-

Table II — Properties of Irons Tested

Mark	Brinell Hardness	Tensile Properties			
		Ultimate	Yield	Elong.	R. of A.
	Flake Graphite Cast Iron*				
Acicular, 263	263	59,700			
Fine, 225	225	45,000			
Coarse, 195	195	35,000			
Ferrite, 100	100	15,700			
	Spheroidal Graphite Cast Iron†				
2%, 265	265	97,250	78,000	2.0	1.5
4%, 215	215	93,000	72,000	4.0	3.5
17%, 207	207	84,700	69,800	17.5	16.5
20%, 183	183	77,100	62,000	20.0	21.0
22%, 170	170	70,000	56,000	22.0	22.0

*From 1.2-in. arbitration bars.

†Cast specimen: 1-in. keel bar cast in dry sand. Test specimen: Standard round test specimen, A.S.T.M. E-8, with 2-in. gage length. Yield strength measured at 0.2% offset, or by the dividers method at 0.5% extension under load.

dritic carbides which may be present, especially in thin sections, ¼ in. or less. Whenever such primary carbides are present, this treatment is advisable. Obviously, the section size and rate of cooling are often such that the casting contains no excess carbides, and this portion of the "standard" cycle may be eliminated. The ductile iron compositions we have tested show that heating at 1600 to 1750° F. does not alter measurably the rate of pearlite decomposition in the second portion of the cycle at 1275° F., below the lower critical temperature. For example, a casting somewhat higher in carbon and lower in silicon than the sample labeled 20%, 183 in Table I but otherwise of quite similar chemical composition was given the double cycle (30 min. at 1750° F.; 2 hr. at 1275° F.) and retained 10% of pearlite in the matrix.

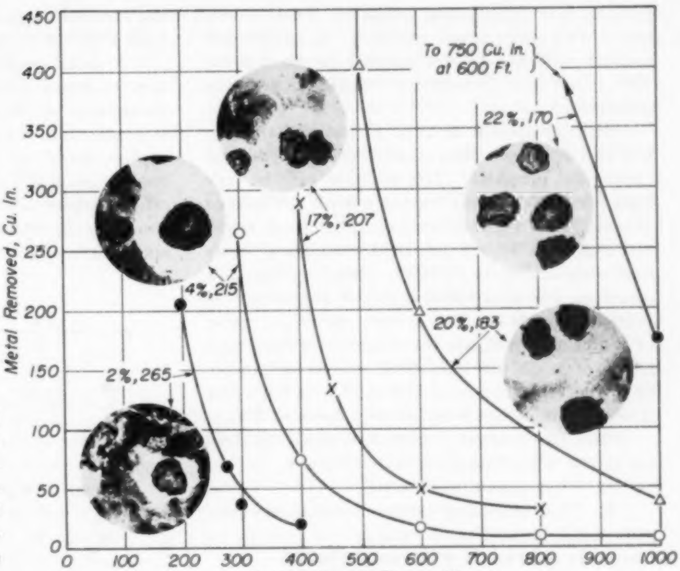

Fig. 2 — Machinability of Cast Irons Containing Spheroidal Graphite. Elongation (tensile), Brinell hardness and structure noted for each variety

Another portion of the same casting that was annealed 2 hr. at 1275° F. (omitting the first portion of the standard cycle) retained 15% of pearlite in the matrix.

In order to reach a 10% pearlite level in the above experiment the time required was 2½ hr. instead of 2 hr. Furthermore, machinability evaluation reveals little difference over a range of from 5 to 15% pearlite in the matrix. To date there haven't been sufficient data to evaluate comparative physical properties, but the limited information available shows no marked variation in the standard tensile properties.

Whenever primary carbides are present in the as-cast structure in significant quantities, heat treatment at 1600 to 1750 °F. is mandatory. Some of the carbidic ductile irons (analogous to white cast irons) contain as much as 60% primary carbide. The lower left curve of Fig. 3 represents the time required to decompose carbide in such an iron containing 30% carbide as-cast. Only 15 min. at 1650° F. was required to lower this percentage to 7% and leave it well distributed in small particles in the matrix. An additional 45 min. (60 min. in all) was required to remove all but 2% of the carbides. If subsequent low-temperature annealing converts the

Table III — Relative Cutting Speed for 200-Cu.In. Tool Life

Flake Graphite Irons					Spheroidal Graphite Irons			
Material	Hardness	Ultimate	R. A.	Speed	Material	Hardness	Ultimate	R. A.
Acicular	263	59,700	0	150				
				200	2% (as-cast)	265	97,250	2
Fine pearlite	225	45,000	0	310	4% (as-cast)	215	93,000	4
Coarse pearlite	195	35,000	0	325				
				420	17% (as-cast)	207	84,700	17.5
				600	20% (annealed)	183	77,000	20
Ferrite (annealed)	100	15,700	0	960				
				970	22% (annealed)	170	70,000	22

pearlite into ferrite and graphite, there is evidence that this small quantity of permanent carbide will not be detrimental in machining. This is not true, however, if the matrix remains pearlitic.

Heat treatment at 1275° F. has as its objective the decomposition of pearlite to ferrite and spheroidal graphite. The reaction rate is very high for ductile irons having a *high* percentage of combined carbon; in fact, the most rapid rates at 1275° F. are achieved with those irons that were originally "white". Reaction rates are also high during the first hours of annealing. A typical example is given in the upper right curve of Fig. 3, which shows the progress of decomposition of a ductile iron with matrix originally 60% pearlite. It was reduced to 25% in 2 hr. and it took 14 hr. more to bring this down to 2%.

The most salient conclusions gathered thus far in the annealing of ductile irons are:

1. That annealing is rapid.

2. That annealing is very rapid if one permits small quantities of carbide and pearlite to remain in the matrix structure of ferrite.

It has been shown in Fig. 2 that a ferritic matrix retaining as much as 20% pearlite affords excellent machinability. Further studies are planned for evaluating the influence of small quantities of carbides.

Applications

A survey of applications in the high-production automotive, tractor and engine fields reveals that a considerable potential exists for the use of ferritic ductile iron for high production as well as high strength. Such parts as cylinder heads, pump bodies, manifolds and housings are particularly suited. In addition, many parts now made of high-strength gray irons can be converted to ferritic ductile irons with an increase in machinability without loss of strength.

Manufacturers of compressors, paper mill machinery and those in the heavy machinery field find the high modulus of ductile iron, coupled with high strength and castability, enables them to replace steel castings at comparable costs. Further, the greater facility with which the magnesium-treated iron is machined effects savings of 20 to 40% on the former cost of the finished components.

Some specific items may be mentioned. A 10-in. annular gear with coarse teeth on the edges has replaced a gray iron clutch part made by a prominent manufacturer, eliminating breakage in service and at the same time lowering production costs because of the greater ease with which it is machined.

A diesel engine builder finds that in addition to lower machining costs, pistons (6 in. diameter) of ductile iron with its excellent strength and ductility permit an increase of engine speed by 50%, thereby up-rating the engine output. Similar experiences have led other people in this field to specify these new irons for flywheels and engine heads as well, since increased speed imposes increased accelerating forces, in turn requiring material of higher strength.

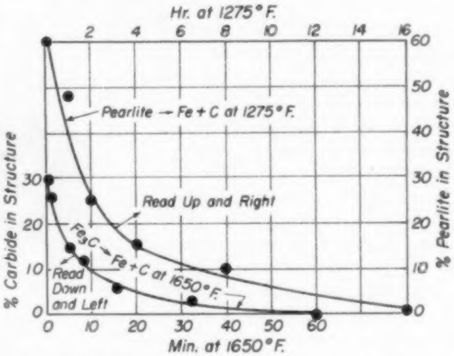

Fig. 3 — Time Required at 1650° F. to Break Up Primary Carbide in As-Cast "Carbidic" Iron and to Transform Pearlite Into Ferrite at 1275° F. The iron represented by the upper curve was not given a prior austenitizing treatment

Hydraulic transmission gears are of rather complicated shape, require good dynamic balance and much machinability. A 12-in. diameter gear of this sort demonstrates the desirability of machining ease; for this reason, along with ductility and adequate strength, the manufacturer adopted ductile iron.

Partially machined pump impellers clearly demonstrate the advantage of ductile iron, which can survive blows from tramp solids without wrecking the entire mechanism.

Castings in volume production offer fertile fields for full realization of the structure-machinability relationship of this new, interesting, engineering material.

ACKNOWLEDGMENTS — The ductile cast irons for these tests were supplied by The International Nickel Co., Inc., by whose process they were produced. The complete cutting tests made by Metcut Research Associates can be found in "U. S. Air Forces Machinability Report, 1950" published by the Curtiss-Wright Corp.

By The Editor

Critical Points

Power From the Atom

IMMEDIATELY after the wartime censorship was removed on the topic of nuclear energy, popular scientific writers rosily predicted a brave, new world where power is had for nothing and so could perform such miracles as irrigating Nevada deserts with distilled sea water! Doubts soon appeared. Undoubtedly enormous heat is generated, but where, for example, could be found a refractory and scale-proof "boiler tube" with excellent heat conductivity, one that would not absorb free neutrons and so quench the nuclear fire, nor alloy with a liquid metal circulating medium?

Each semiannual report of the U. S. Atomic Energy Commission outlines a great amount of work on this problem of nuclear power, but each official pronouncement seems to postpone the expected date of fulfillment. There are so many possible combinations of high, medium, or low temperature level, graphite or heavy-water moderator, pile or homogeneous, uranium or breeder reactor. Then wrap this whole matter up in secrecy and it is not surprising that credible estimates of *costs* of nuclear power are absent. Far from costing nothing, operational costs are obviously considerable, even if the fuel itself comes free.

Estimates presented by C. G. Suits, director of research of General Electric Co., to the recent Cleveland meeting of the American Association for the Advancement of Science are therefore enlightening. He postulates that only a large power plant can be competitive — on the order of 500,000 hp. In "Case A" he assumes the cost of nuclear fuel to be equal to the cost of coal per B.t.u., that plant operation costs are equivalent, and that nuclear byproducts can be wasted. On this basis the reactor cannot cost more than $11,000,000 to compete with a typical large steam-electric plant. In "Case B" he assumes that nuclear fuel can be regenerated and so would cost nothing; in that event the reactor could cost $38,000,000 and still compete. "Case C" assumes that spent nuclear fuel can be sold for its plutonium content at a profit equal to the cost of coal consumed by a competing steam-electric plant; then the reactor might cost $65,000,000.

After considering the available information, including the $25,000,000 cost of the 40,000-hp. reactor at Brookhaven National Laboratory, Suits concludes that $50,000,000 to $100,000,000 represents the cost of building a large reactor under current limitations of technology. It follows that only a breeder reactor ("Case C") would be competitive in present-day America.

Studies on Jet Engines

A RECENT AFTERNOON spent at the extensive and expanding Lewis Flight Propulsion Laboratory of the N.A.C.A. (National Advisory Committee for Aeronautics) near Cleveland's Municipal Airport indicated that the investigators there — once busy with internal combustion reciprocating engines — are now pre-occupied with gas turbines and even higher-speed rockets. Judging from the metallurgical work in progress, rapidly inspected under guidance of Mervin Ault of the Materials Research Section, the bottleneck in jet engines is the turbine bucket or blade, although liners for combustion chambers and tail cones seem to be working near their maximum limit at present. Since each American engine manufacturer now has his own preferred blade alloy (without much clear-cut evidence for the choice), these commercial materials are under intensive study, not only by creep, stress rupture and fatigue testing at high temperatures, but also as blades mounted in superchargers or turbines and operating so as to correlate test values with actual performance.

Supercharger wheels are used to test the effect, say, of a definite heat treatment on performance of blades. A whole wheel will be equipped with blades of a single lot, all identical as far as acceptance tests can determine. Run this wheel at controlled speed and temperature until the first blade fails; replace it; start up and continue until the next blade fails; replace it; and so on until the last of the original blades

gives up the ghost. If cumulative failures in such a test are plotted against time, the graph is a frequency curve. The practical problem is to move the *beginning* of the curve to the right — in other words, it is the life of the *poorest* blade that determines the life of the engine.

Among the interesting facts already discovered by this method of experimentation is this: If some of the present high alloys, ordinarily used as-cast, are properly aged, the earliest fracture at a given working temperature is noticeably postponed; furthermore, an optimum heat treatment seems to move the entire curve to the right, toward longer times. Another notable finding of more conventional testing concerns surface finish of coarse-grained test pieces, either finish machined, ground, or polished; this has considerable influence on, say, the fatigue resistance at atmospheric temperatures, but very little at 1000° F. and higher. . . . One gathers from conversation with various engineers at Lewis Laboratory that they have little hope for boosting the engine temperatures more than a couple of hundred degrees with bare metal blades (although Howard Scott of Westinghouse would say, "Don't sell molybdenum and its alloys short!"). Metal coated with ceramic oxides or silicides would be useful in somewhat higher ranges were it possible to make a coating absolutely free from pinhole porosity. Seemingly the best present hope for turbine parts to operate in the range of 2500° F., where a great gain in a turbo-prop engine's thermal efficiency can be predicted, is to make them of mixtures of refractory metals and ceramics or to make blades entirely of a refractory substance. As an instance of the latter, molybdenum disilicide ($MoSi_2$) is attracting attention. The powdered and purified chemical is pressed approximately to shape, lightly sintered, machined close to finish with carbide tools, fully sintered, then ground with diamond abrasives to final size. It is quite brittle at room temperature and therefore the problems of manufacture, shop assembly and overhaul are imposing. However, at working temperature, the silicide is surprisingly strong and ductile — properties which indicate, perhaps, some forgeability. As mentioned, though, assembly without cracking will involve most careful handling, improved attachments, and means of discovering unfailingly an all-but-invisible crack. . . . For the tests at high temperature there is a wealth of ingenious equipment available, some units operating steadily at 3500° F. in vacuum or helium atmosphere. Simple transverse bending tests (the sample and fixtures at high temperature) are relied upon in preliminary surveys of proposed alloys or compounds to separate the sheep from the goats. Any interesting formulation must also pass the heat fatigue test, wherein a sample is heated repeatedly to incandescence and then quenched in a blast of cold air. Instrumentation of the engines during a test run is also quite ingenious and complete; temperature of the blades is measured, for example, by leading noble metal thermocouples from an appropriate slip ring through hollow shaft and up axial holes within the blades themselves, ending at the required position. It's the temperature of the *metal*, not the gases, that is important.

Productivity of Labor in Steelmaking

MORE THAN ONCE it has been remarked in "Critical Points" that the labor-saving trend of technological advances and managerial skill, while undoubted, is very hard to evaluate quantitatively. Comes now a little book by William T. Hogan of Fordham University's faculty containing a careful analysis of "productivity in the blast furnace and openhearth segments of the steel industry from 1920 to 1946". He studied the records of a single large steel plant, having eight blast furnaces with maximum annual production (in 1944) of 2,290,000 net tons, and 16 openhearths which produced about 1,700,000 net tons of ingots in 1942, again in 1943, and again in 1944. . . . Total direct labor plus distributive labor of general yard gangs and so on averaged 2.36 man-hours per net ton of pig iron in 1920 to 1924 and 0.75 man-hours for 1942 to 1946 inclusive. Despite a steady increase in average wage rates from 56¢ per hr. in the early 1920's to $1.17 in the mid-1940's, the labor cost of smelting iron ore has been reduced from $1.32 to 88¢ per ton. Professor Hogan remarks that "the wage rate bears little if any causal relation to productivity or man-hours per ton in this plant. This phenomenon is not at all surprising when consideration is given to the fact that man-hours per ton are a direct result of efficiency within the plant itself, whereas wages are determined by bargaining on a company-wide [or industry-wide] basis". . . . Corresponding figures for openhearth production are as follows: One net ton of ingots cost 3.29 man-hours at 56¢ per hr. or $1.84 in 1920-1924, and 1.53 man-hours at $1.17 per hr. or $1.79 in 1942-1946. Apparently the labor-saving devices in a modern openhearth shop have hardly been able to keep ahead of the increasing cost of the labor that must still be expended.

By Adolph Bregman
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(*Consulting Editor for* Metal Progress)

Antimony Plate

Antimony is a metal known (and used somewhat sparingly) since ancient times. Its consumption in quantity came with commercial use of its alloys with lead (with which it is commonly associated in nature, and therefore is a "natural" alloy coming from the smelter). Noteworthy are type metal, bullets, babbitts, and storage battery plates. It is available in tonnage in 99.8% purity, but is seldom used in this condition, despite some interesting properties — notably, high resistance to industrial atmospheres, to oxygen-free hydrochloric acid, and to hydrofluoric acid. On the debit side, it is as weak as lead (tensile strength about 1600 psi.) yet as hard as zinc (Brinell 40) and very brittle. An ancient use was for mirrors; buffed surfaces have a higher reflectivity than chromium, although not as high as silver.

The physical defects might not be so damaging if antimony were used as an electroplate on stronger, tougher metal; however, only recently have methods been developed. Antimony is refined electrolytically from thio-antimonate (Na_3SbS_4) solution, but the cathode deposits are brittle and poorly adherent and can be easily knocked off the cathodes with a hammer. Attempts to electroplate antimony have generally resulted in deposits so brittle that they flake off by scratching or slight bending.

Two new processes have recently been reported; one uses antimony trifluoride and is patented (No. 2,389,131) by M. C. Bloom, while the other (reported in *Plating*, March 1950 issue, by Soderberg and Pinkerton) uses complex citrate baths. According to the last-mentioned account, the bright antimony deposits were brittle and highly stressed, yet were originally free of any cracks visible under the microscope and remain so after three years. Dull and semibright deposits up to 0.001-in. thickness could usually be brought to a very high luster with a light buffing operation; they were also adherent in a bend test and reasonably ductile. The authors state that although the production of commercially desirable, fully bright antimony deposits has not been achieved, their somewhat less lustrous deposits would undoubtedly have considerable commercial value when buffed.

This matter of easy buffing to a high finish is uniquely important. Antimony plate flows easily under the buff. Antimony, therefore, may be plated directly on a comparatively rough surface and then, because of its high "buffability", polished or "colored" up to a high luster within much less time than would be required to produce an equally high finish on the steel base. Consequently, a highly polished steel surface is not required prior to the deposition of antimony by the Bloom process — a significant element in cost savings. In fact, a certain roughness is actually desirable in the base, as will be demonstrated later in this article.

Chemical Stability — One observation of importance is worth noting. In December 1936, Dr. Bloom had occasion to cast a single crystal of antimony. The metal is hexagonal in structure and shows such perfect basal cleavage that the cast specimen exhibited a mirror-bright cleavage surface. This surface remained in a chemical laboratory for four years and has subsequently had 10 years of normal indoor exposure. It remains, in microscopic appearance, as bright as the day it was cleaved. Another cleavage surface, exposed for six months to the urban atmosphere of Newton, Mass., only slightly decreased in luster.

Electrodeposits 0.0015 in. in thickness upon mild steel have shown resistance to indoor and outdoor environments entirely analogous to that of these cleavage fragments. Samples subjected to indoor exposure for more than three years showed no evidence of tarnish. Comparative outdoor exposure tests of sheets plated to 0.0015 in. with copper, nickel and chromium, on one hand, and antimony on the

It is not generally appreciated that pure antimony resists attack by hydrochloric and hydrofluoric acids, is relatively tarnish resistant, and easily buffed to a highly reflective surface. Successful plating techniques make it a substitute for the more critical metals, nickel and chromium.

other, have revealed that although the tarnish resistance of the antimony coatings is less, its original luster was restored by light rubbing with a metal polish, such as is normally used for brass. A combination of the corrosion resistance of antimony and the tarnish resistance of chromium has been obtained by a flash coating of chromium upon the buffed antimony.

Aside from this relative stability in the atmosphere, antimony has a corrosion resistance, not generally recognized, which is greater in many respects than that of any metal now commonly used for plating except the precious metals.

At room temperature, antimony is inert to sulphuric acid of any concentration and is attacked by nitric acid only when concentrated. The metal is inert to hydrochloric acid of any concentration in the absence of air, but is slowly attacked by the strong aerated acid. In general, antimony is resistant to all environments wherein the oxide Sb_2O_3 is sparingly soluble. This embraces nearly all normal industrial environments except fluoride, tartrate, oxalate, citrate and highly alkaline solutions.

Pretreatment Before Plating

It is a fact well known in electroplating generally (and particularly in nickel plating) that, in order to attain the optimum adherence as well as the minimum porosity, the conducting surfaces upon which the coatings are to be deposited should be as smooth as possible. Thus, the normal procedure in modern electroplating upon steel is to start with surfaces with as high a polish as can be economically attained.

However, it was found by Dr. Bloom that the best results in the electrodeposition of ductile and malleable antimony followed a procedure substantially the antithesis; the best results are attained when the conducting surface already possesses, or has had imparted to it, a certain measure of roughness or superficial irregularity — imparted either by mechanical means, such as sandblasting, frictional engagement with abrasive agents, or passage of the material through a roughened roll, or by chemical etching. Such slight superficial irregularity is indispensable, yet more pronounced roughness increases unnecessarily the difficulty of attaining buffed surfaces of mirror-like finish, should they be desired. Two methods are suggested:

1. The smooth conducting surface is roughened by mechanical means, and then, if it is not clean, subjected to the customary cleaning techniques employed in the electroplating industry; it is then rinsed in water, then subjected to the usual activating pickle to remove scale and to destroy passivity; then given a final rinse in water, whereupon, if no water breaks are observable, the roughened conducting surface is ready for the electrodeposit.

2. The smooth conducting surface, if it is dirty, is subjected to the customary cleaning techniques, then rinsed in water, then etched by a suitable corrosive substance, then rinsed in water. It is then subjected to the usual activating pickle to remove scale and smut and to destroy passivity, given a final rinse in water, whereupon, if no water breaks are observable, the etched conducting surface is ready for the electrodeposit. Suggested etchant for a mild steel surface is a solution of nitric acid of moderate concentration; for copper, anodic electrolytic action in a solution of phosphoric acid; for aluminum, a solution of hydrochloric acid of moderate concentration.

Bath Compositions

Baths containing antimony trifluoride and a fluoride of a monovalent base will yield superior results. Specifically, it was found that baths comprising antimony trifluoride (SbF_3), ammonium fluoride (NH_4F), and ammonium hydroxide (NH_4OH), in aqueous solution having a hydroxide ion concentration somewhat less than necessary to produce precipitation, yield electrodeposits of antimony possessing the most desirable characteristics of ductility, malleability and adherence. If preferred, antimony oxide (Sb_2O_3) may be substituted for antimony trifluoride, and

ammonium hydrogen fluoride (NH_4HF_2) for ammonium fluoride, in making up the bath.

In previous work, some question has arisen regarding the development of brittleness in antimony electrodeposits on aging. According to Bloom, it is important to note that this phenomenon, which is observed with electrodeposits of antimony over copper, is due to a rather remarkable room-temperature diffusion which forms the brittle compound Cu_2Sb. Deposits of antimony over steel a number of years old show no analogous tendency. Such samples more than five years old have been subjected to rough bending and impact tests with no observable difference in their behavior from that observed when they were first prepared.

Equipment and Operation

Necessary equipment differs in but few respects from that required for deposition of bright nickel deposits.

Power requirements for a given thickness of antimony are somewhat more than half of those for an equivalent thickness of nickel. With the current densities in normal use in electroplating tanks, a 0.001-in. coating may be applied in somewhat less than 30 min.

The throwing power of the bath is not greatly different from that of bright nickel.

Advantages

1. These antimony coatings take a high polish readily, producing surfaces of silver-like appearance with a reflectivity higher than that of chromium.
2. In indoor environments, including the acidic atmosphere of the chemical laboratory, these highly polished antimony coatings remain bright for indefinite time.
3. Salt spray tests indicate a resistance to marine environments equal, if not superior, to that of the best copper-nickel-chromium coatings of equivalent thickness.
4. These plated coatings of antimony will resist the action of most industrial solutions, especially acids, more effectively than similar plates of any other of the nonprecious metals.
5. Costs are lowered by eliminating the preliminary polishing of the basis metal to produce a high finish.
6. One property of these deposits which makes them especially suitable for electrical and other complicated metal products is their easy solderability.

Disadvantages

1. The resistance of antimony to scratching is greater than that of lead, tin, zinc, cadmium, silver and copper, but less than that of iron, nickel and chromium.
2. Although data are meager, it would appear that the soluble salts of antimony are sufficiently toxic to prevent its use in food containers.
3. As a protective coating for steel, antimony (like nickel, copper, tin, lead, silver and gold) functions solely by virtue of its own resistance to corrosion, and not (like cadmium and zinc) by preferential corrosion. For that reason, electrodeposits of antimony require a high degree of freedom from porosity.
4. Antimony melts at 1167° F., so it cannot be used at very high temperatures.

Uses and Applications

Obviously, many uses of metals are affected by their relative abundance, especially in wartime. Antimony is regarded as a strategic metal, being classed with others like manganese, tin and tungsten wherein from 50 to 75% of our current needs are imported. Antimony remained under Government allocation after World War II until late in 1947. China, formerly the principal source of cheap metal, has exported comparatively little for several years. America needs some 40,000 tons of metal per year; about 25,000 tons are recovered annually from secondaries (principally old battery plates), about 5000 tons of new metal come from mines in Idaho, and about 10,000 tons are imported from Mexico and Bolivia.

However, the supply of antimony in relation to its necessary uses is considerably more generous than the supply of chromium and nickel. Consequently, antimony might well be considered for a corrosion resistant surface on many parts where more critical metals are now being used, such as hardware parts, domestic ware, automotive trim, parts in radio and radar equipment which require a high degree of corrosion protection and which, for performance reasons, must be soldered, and for castings, forgings and other rough metal parts which otherwise would require heavy grinding and polishing before plating.

In addition, there are unique uses for the material opened by virtue of its resistance to corrosion by HCl, cold H_2SO_4, dilute HNO_3, and a variety of industrial environments. Searchlights, floodlights and mirrors can also be made, because of antimony's high reflectivity and resistance to tarnish in the atmosphere.

Correspondence

Effect of Shot Peening on the Brittle Transition Temperature

SCHENECTADY, N. Y.

In Fig. 2 of his article "Effect of Shot Peening on the Brittle Transition Temperature" in the September 1950 *Metal Progress*, Nicholas Grossman shows an increase in transition temperature for a 1020 steel as a result of heating at 450° F. following shot peening. This increase the author attributes to the relief of residual stresses at the notch surface of his specimen. Although no time is given, it seems unlikely that any appreciable reduction in residual stress could be accomplished at this temperature, in a steel, in any reasonable time. An alternative explanation of the observed result might well be that strain aging, with a resultant rise in transition temperature, has occurred in the cold worked layer resulting from shot peening. If so, the reduction in transition temperature achieved by shot peening is transitory and should disappear with time even at room temperature in steels, such as the one used, which are susceptible to strain aging.

JOHN R. LOW, JR.
Knolls Atomic Power Laboratory
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European Research on Flame Radiation

LONDON, ENGLAND

The radiation of flames influences greatly the design and efficient operation of openhearth furnaces and boilers in modern heavy industries. Comparatively little research has been carried out on the subject of obtaining the maximum radiation from a given flame, and it is interesting to hear that scientists of France, Holland and Great Britain, to be joined later by a Swedish worker, are cooperating in an investigation of the factors affecting luminous flame radiation, using an experimental furnace in the Royal Dutch Steelworks at Ijmuiden, Holland. The furnace chamber is box-shaped, about 20 ft. long and 6½ ft. square. Vertical slots in both side-walls permit radiation measurements to be taken. The slots may be closed with water-cooled "doors". No charge or load is in the furnace. The refractory walls and roof are about 10 in. thick. Firing one way only, the flame goes horizontally through the chamber, and flue gases are drawn off through a stack of venturi shape. Oil flow and temperature, air flow, atomizing air or steam, furnace pressure, wall and roof temperatures, and flame radiation are carefully metered.

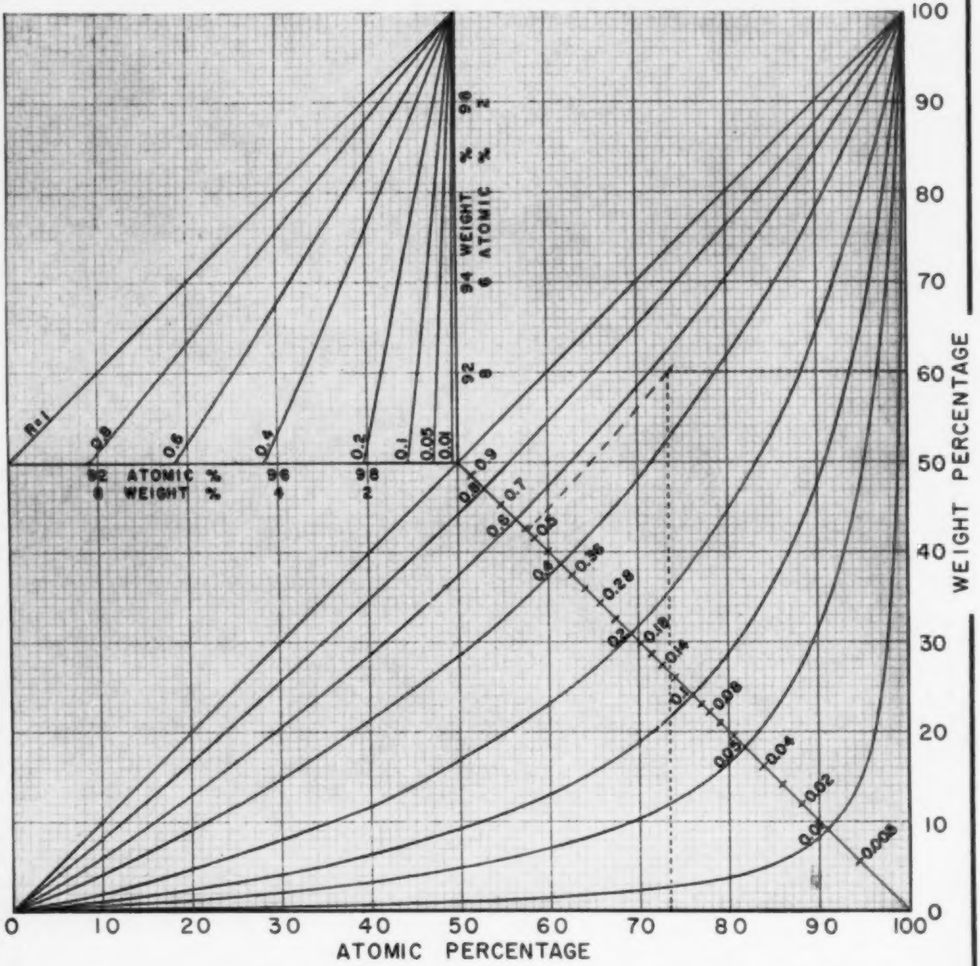
Work is supervised by committees set up in the three countries, each supported by many firms and organizations in their own country. The respective chairmen are: France, G. M. Ribaud (director of research for the French gas industry); Great Britain, O. A. Saunders (Imperial College of Science and Technology); and Holland, J. E. de Graaf (head of research for the Royal Dutch Steelworks). In general charge is M. W. Thring, head of the British Iron and Steel Research Association's physics department.

Two kinds of trials are being undertaken, termed respectively "engineering" and "scientific". In "engineering" trials a large number of independent variables, such as fuel rate, kind of fuel (various oils, pitch, pulverized coal, coke-oven gas), type of burner or port, excess air ratio, are altered systematically and a limited number of radiation, temperature and combustion properties of the flame are measured for each flame setting. In "scientific" trials, a relatively small number of different flame settings are to be studied in great detail by means of probes so that, for example, the course of combustion of individual droplets, the mechanism of soot formation and the emissivity and temperature of different parts of the flame can be elucidated in detail. It is felt that this more fundamental approach is likely in the long run to lead to results at least as practical as those obtained by the more empirical approach of the engineering trials.

A number of preliminary experiments have now been made. One task has been to choose the best *(Continued past insert)*

Interconversion of Atomic % and Weight %

By Robert J. Raudebaugh
Professor of Metallurgical Engineering, Georgia Institute of Technology



IN A.S.M. Metals Handbook, 1948 edition, p. 196 *e.s.*, a formula is presented for interconversion of atomic and weight % in binary systems, and tables of logarithms for various terms in the formula, which give an accuracy of 0.01%. The above family of curves is based on the Handbook's formula. The values indicated on the 45° bisector represent the ratio $R = M \div N$, where M is the atomic weight of the lighter element and N is of the heavier.

Solution is indicated for a Cu-Sn alloy of 60% Cu by weight. For this case, R = (63.54 ÷ 118.7) = 0.53. Curve for 0.53 is interpolated by the dotted line upward until it meets the horizontal ordinate for 60% by weight. Projecting vertically downward from this intersection the atomic % is read at 73.5. (Calculated value by Handbook tables is 73.7 atomic % Cu.)

The insert at the upper left is an enlarged plot of the extremities of the large chart, and provides more accurate estimates in the 90 to 100 (or zero to 10) percentage regions.

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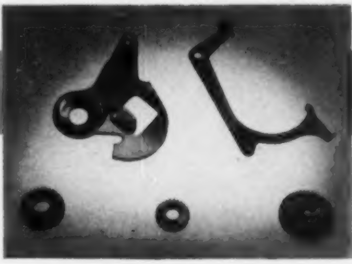

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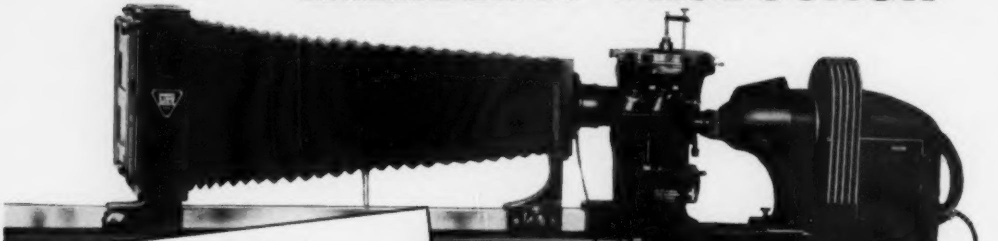

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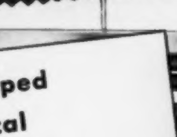

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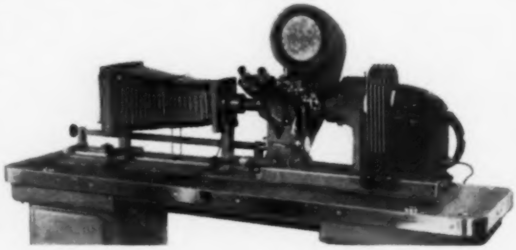

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instruments for the engineering trials, and to equip the furnace to the best advantage. Statistical methods have been used to plan the first series of engineering trials. It was decided to choose five variables (creosote pitch versus oil, high and low combustion air rate, high and low fuel rate, high and low atomizing medium flow rate, and air versus steam as atomizing medium) and to carry out 48 trials according to a *factorial* scheme. This has been the first attempt to apply to a large-scale furnace these methods of designing experiments, which were originally developed for agricultural trials. Most of these trials have now been successfully completed and the results are expected not only to provide useful scientific information, but also to indicate the most valuable means for continuance.

Tom Bishop

Cyclic Annealing

Wilmington, Del.

In the June 1950 issue of *Metal Progress*, Messrs. Adam and Rosseau ("Modern Heat Treating") indicate that in cyclic annealing "the steel is heated first to the austenitizing temperature and then quenched in another bath operating in the range of 1100 to 1300° F. where it remains for the time indicated by the S-curve for that particular steel to complete transformation. The austenite transforms directly to the desired soft structure of ferrite and pearlite. Then the work can be cooled in air or water as rapidly as possible."

I would like to call attention to the fact that despite the advantages claimed for cyclic annealing, the above process could lead to serious consequences if residual stresses must be absent in the product. Quenching from as high as 1300° F. can lead to high-order residual stresses, as has been shown many times by investigators in the field of stress analysis. Cognizance should be taken of this possibility in evaluating the merits of cyclic annealing.

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Effect of Nuclear Radiation on Metals

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In the article by D. S. Billington and Sidney Siegel on "Effect of Nuclear Radiation on Metal" in the December 1950 *Metal Progress*, the authors attribute the increased hardness and resistivity noted after irradiation in beryllium-copper largely to lattice distortion.

Item 4 states that the more beryllium in alpha solution the greater the effect of irradiation. Cases cited include *(a)* the solution annealed state which contains the most beryllium in alpha solid solution, *(b)* overaged samples which are heated at temperatures higher up on the solubility curve and thus contain more beryllium in solution, and *(c)* underaged samples which have not precipitated as much beryllium as γ phase as fully-aged specimens.

On the basis of the evidence presented, could not these effects be also explained by lattice distortion? The beryllium content of a cold worked alpha solid solution is as high as that of a solution annealed sample; however, the expanded lattice of the former does not permit as great subsequent distortion by irradiation. At any of the normal aging temperatures, beryllium-copper (in time) passes through a complete cycle from underaged to peak hardness to overaged. During underaging the lattice expands with time, reaching a maximum, and then contracts during overaging. Therefore, there is room for expansion in either underaged or overaged specimens exposed to nuclear radiation, the potential distortion depending on the degree of underaging or overaging. This effect is probably considerably greater than that from any increase in solubility with temperature, particularly where equilibrium is not reached.

In the example given, prolonged heating at 565° F. will probably cause overaging with a decrease in resistance, lattice size and the amount of beryllium in solution. Consequently, irradiation can again cause lattice distortion and an increase in resistivity, in spite of decreased beryllium in solution.

A possible explanation for the anomalous behavior occurring in the resistance of cold worked material upon heating for 5 min. at 565° F. may lie in stress relief. At 565° F., the hardening rate is low; however, stress relief is rapid and some of the internal stress resulting from cold work is relieved, thus increasing the potential for lattice distortion.

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Relation of Structure of Stainless Steel to Hot Ductility

A HOT TWIST TEST to determine hot ductility was first described by the late Prof. Albert Sauveur in 1929. Its application by H. K. Ihrig (and later by C. L. Clark and J. Russ) for determining the optimum temperature for hot piercing and forging various steels has been reported in some detail.[1] Since these investigators have fully described the apparatus and the test procedure in the literature citations on p. 256, they need not be repeated in detail here. Briefly, the test consists of inserting a round bar of uniform dimension through a tubular furnace, bringing the center portion in the furnace to the test temperature, clamping one end of the bar and twisting the other end. The number of twists necessary to fracture the hot material is determined; sometimes torque is measured, also.

The total turns to fracture include not only those resulting from twisting the specimen in the section at the selected test temperature, but those resulting from twisting in sections away from the hottest center section. This procedure therefore involves the twisting of a test specimen over a temperature range. As a result, the total number of turns may be affected by the length of the hottest zone in the furnace and the general temperature gradient existing throughout the specimen's length. Despite these limitations the twist test has a definite value in that it provides a quick, simple method for obtaining an approximate measure of the ductility (workability) of materials at different temperatures, although the numerical values obtained have no direct engineering application.

The test values are greatly enhanced when interpreted in the light of the microstructure of the material at the test temperature. It often appears that the temperature of optimum ductility can be directly related to the presence or absence of certain microstructural constituents.

Clark and Russ in their 1945 paper in *Metals Technology* have suggested that each steel possesses a critical temperature as far as its hot twist ductility is concerned; above this the ductility will decrease with increasing temperature. They believe that this critical temperature is the equicohesive temperature of the steel for the particular strain rate involved. In the present authors' experience, at least with stainless steels, these maxima in the ductility-temperature curves seem more rationally explained by changes which occur in the microstructure of the alloys as the temperature is increased. Whereas the hypothesis advanced by Clark and Russ may account for one peak in the ductility-temperature curves, it fails to explain such instances as those observed by us wherein the first maximum is followed by a second increase in ductility with increasing temperature. Such reversals in ductility as will be described in the present paper can readily be explained in terms of microstructural changes.

The thought that the microstructure of steel may affect its hot ductility is not new. Sauveur drew attention to the marked changes in ductility occurring at the A_3 temperatures of the carbon steels tested by him. His data clearly demonstrate a relation between the twist values and thermal critical points. This concept is particularly significant when applied to stainless steels, because their thermal critical temperatures (transformations) frequently coincide with the temperature range common to hot working operations.

In our experiments, centerless-ground bars, $\frac{9}{16}$ in. in diameter, were employed. Samples were twisted at various levels ranging from 1900 to 2450° F. (1040 to 1340° C.) after being held at temperature for 20 min. The number of turns was recorded and the data plotted against test temperatures. The corresponding microstructures were determined by examining separate samples heated to the test temperature and brine quenched. This method was used since microsections taken at the point of failure of twisted bars frequently showed severely torn metal, and usually contained so much embedded scale that interpretation of the structure was extremely difficult.

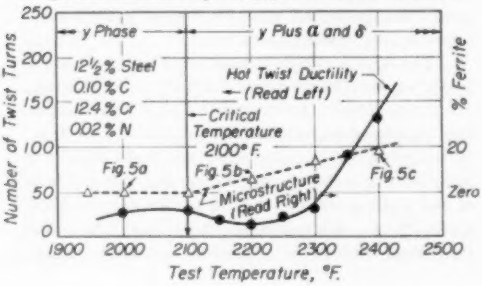
For convenience of discussion, stainless steels may be divided into two broad groups:

A. The chromium steels in which chromium is the principal constituent (Cr 11.5 to 27%).

B. The chromium-nickel steels containing both chromium (16 to 26%) and nickel (6 to 22%), as well as smaller amounts of titanium, molybdenum or other alloying elements.

The two classes of alloys differ markedly in microstructural characteristics and are, therefore, considered separately.

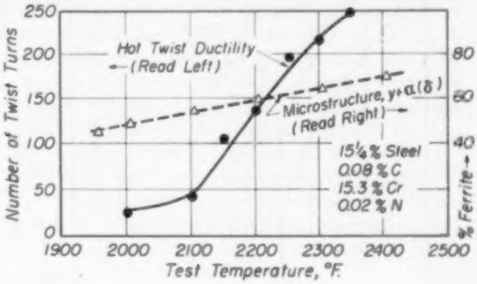
Fig. 1 — Hot Twist Ductility and Corresponding Microstructure of 12½% Chromium Stainless



Straight Chromium Stainless

Figures 1, 2, and 3 show the relationship between number of turns and twist temperature for low-carbon iron-chromium alloys containing approximately 12, 15, and 26% chromium. Data connected with full lines represent typical twist values obtained for a number of heats of the average analysis shown on each graph. In each an attempt is also made to depict the results of microstructural examination of specimens rapidly quenched from corresponding temperatures. This information is plotted in dotted lines; reading to the right is noted the amount of ferrite (alpha or delta phase, or both). The

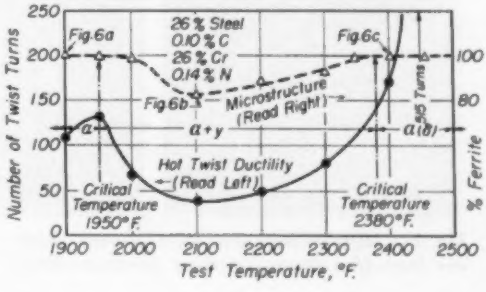
Fig. 2 — Hot Twist Ductility and Corresponding Microstructure of 15¼% Chromium Stainless



balance of the structure is gamma, or austenite. Representative photomicrographs are indexed on these curves — structures of specimens treated at designated temperature levels.

The nature of the structural changes in the chromium alloys will become clear by reference to Fig. 4, which shows a partial section of the iron-chromium-carbon diagram with the characteristic gamma loop at a level of 0.1% carbon as determined by Tofaute, Sponheuer and Bennek.[2] To this has been added in double lines an expanded gamma loop, corrected according to work of the authors, which shifts the location of the austenite, austenite-ferrite, and ferrite phase boundaries to higher chromium levels. This is in conformity with the microstructures actually observed in our specimens. As a matter of fact, careful examination of the German data suggests that the boundaries of the gamma loop, at least at the higher temperatures, have been placed by Tofaute and his co-workers at chromium levels that are somewhat low. A double dotted line has also been drawn by us to show the approximate boundary between the gamma plus alpha and the alpha fields for our alloy containing 0.10% carbon, 26.0% chromium, and

Fig. 3 — Hot Twist Ductility and Corresponding Microstructure of 26% Chromium Stainless



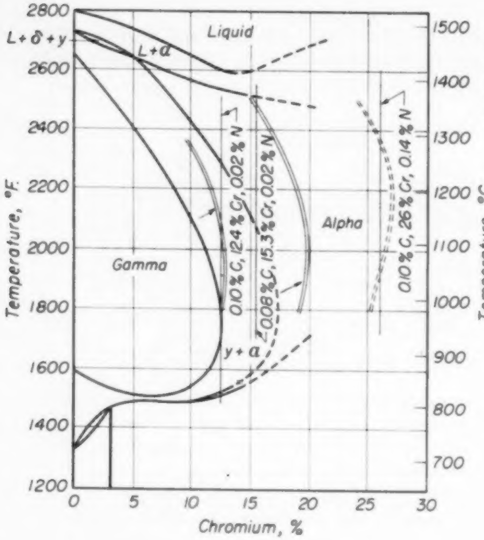


Fig. 4 — Iron-Chromium-Carbon Diagram at 0.10% Carbon Level (According to Tofaute, Sponheuer and Bennek) With Shifted Borders of $\gamma + \alpha$ Field According to Present Work

0.14% nitrogen. Ordinarily, with a low nitrogen content, this composition should be wholly ferritic over the temperature range from 1900 to 2500° F. (1040 to 1370° C.). However, the nitrogen markedly shifts the outer limit of the gamma loop to much higher chromium contents.

For convenience in locating our data, vertical lines have been drawn at chromium contents corresponding to the average analyses of the three types of steels which we tested.

From Fig. 1, 2, and 3 it is clear that a definite relationship exists between the structure of the alloys and their ductility as determined in the hot twist test. It would seem reasonable to expect that, as the test temperature increases, the ductility of the material should also increase. In general, this is true for each of the alloys described herein; however, the increase in ductility is by no means a direct function of increasing temperature. Ductility is strongly affected by structural transformation, and in some cases definite reversals in ductility are exhibited.

The hot twist values of the 12.4% chromium alloys (Fig. 1) increase slowly to a temperature of 2100° F. (1150° C.), then decrease slightly to a minimum at a temperature of 2200° F. (1240° C.), then increase rapidly. In conformance with Fig. 4, microstructural examination shows this alloy to be wholly austenitic up to the transformation temperature of 2100° F. (1150° C). At this point the boundary of the gamma and the gamma plus alpha fields is passed and, at higher temperatures, ferrite appears in the austenite matrix in increasing amounts (as shown by the dotted line in Fig. 1).

This sequence of structures is illustrated in Fig. 5, the microstructure of this alloy after brine quenching samples from 2000, 2200, and 2400° F. (1090, 1205, and 1315° C.). (It should be remembered that the martensitic matrix present in the quenched samples was originally austenite at the test temperature.)

The 15.3% chromium alloy (Fig. 2) shows a fairly regular increase in ductility with increasing temperature. Referring to Fig. 4 it is evident that no phase boundaries are crossed. This type of alloy at all temperatures between 2000 and 2350° F. lies between the inner and outer edges of the gamma loop — that is, in the gamma plus alpha field. Micrographs show that the only structural change is a gradual increase in the

Fig. 5 — Microstructure of 12.4% Chromium Stainless Steel After Brine Quenching Specimens From 2000, 2200, and 2400° F. Respectively. Etchant, picric-hydrochloric acid; magnification, 200×

amount of ferrite and a corresponding decrease in the amount of austenite.

The 26.0% chromium alloys have been extensively studied by H. D. Newell.[4] Our alloy with high nitrogen content, Fig. 3, shows in a striking manner the effect of structural change on hot ductility. At a temperature of 1900° F. (1040° C.) this alloy is completely ferritic. Between the temperatures of 1900 and 1950° F. the ductility increases fairly rapidly. At the latter temperature the phase boundary between 100% alpha and gamma plus alpha is crossed. Austenite appears in the structure, and the ductility immediately begins to fall off rapidly to a minimum at a temperature of around 2100° F. (1150° C.), at which point the percentage of austenite in the structure is at a maximum. Beyond this temperature the amount of austenite decreases and the ductility rises until at about 2480° F. (1360° C.) the number of turns reach the extraordinary value of 515.

The photomicrographs in Fig. 6 illustrate the structural changes. Again the structures conform with those indicated in Fig. 5. After quenching from 2400° F. (1315° C.), it consists of a groundmass of ferrite containing platelets of austenite distributed in a Widmanstätten-like pattern (the right-hand micrograph of Fig. 6). Earlier investigators, notably Krivobok and Grossmann,[3] suggested that is the result of a partial transformation of ferrite to austenite during quenching. This sample was believed to have been completely ferritic at a temperature of 2400° F.

In general, it is not only evident that the structure of the ferritic alloys affects their hot ductility but certain other interesting features are brought to light. The data in Fig. 3, for instance, strongly suggests that the hot ductility of the two-phase structure, ferrite plus austenite, is inferior to that of the ferrite phase alone. This is exemplified by the sharp drop in twist turns at a temperature of 2000° F., and a very sharp increase at 2400° F. Further, from Fig. 1, the conclusions must be drawn that the first appearance of ferrite in a wholly austenitic structure tends to decrease the twist ductility below that of pure austenite. Not until the ferrite content exceeds 15% does the ductility begin to rise strongly with increase in temperature.

This general phenomenon again presents itself in a similar manner in the chromium-nickel stainless steels, and is discussed more at length in the next section.

Chromium-Nickel Steels

Figures 7 to 10 show the relationship between the number of turns and twist temperature for four well-known commercial austenitic stainless steels: 18-10, 18-12-Mo, 19-12-Mo, and 18-10-Ti. Hot twist data again represent typical values obtained from several heats of the average analyses shown on each chart. Each contains results of microstructural examination of specimens which were rapidly quenched from designated temperature levels. The dotted line on the chart defines the phases present, either austenite, delta ferrite, or both, and the relative amounts of each phase at each temperature level. In addition, some photomicrographs of specimens treated at the specified temperatures are included in Fig. 11 and 12.

Because of the number of components in these chromium-nickel alloys, the construction of a constitutional diagram similar to ones presented for the straight chromium alloys was thought impracticable. However, it is well established that, at hot working temperatures, the structure of such alloys should consist of aus-

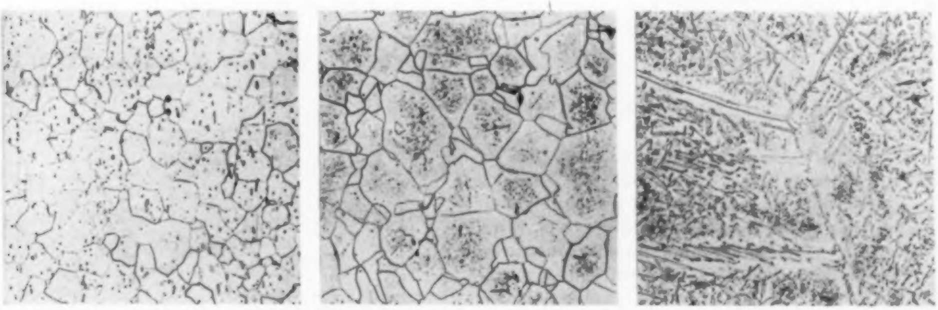
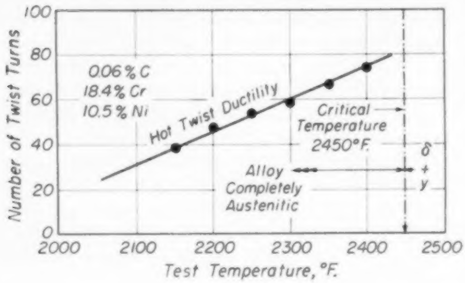


Fig. 6 — Microstructure of 26.0% Chromium Stainless Steel After Brine Quenching Specimens From 1900, 2100, and 2400° F. Etchant, picric-hydrochloric acid; magnification 200×

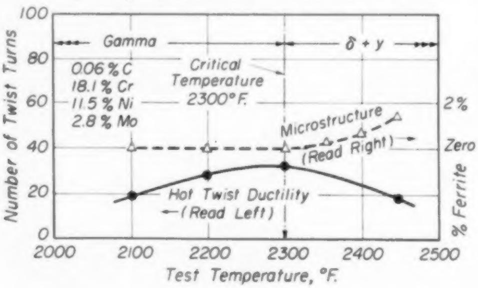
Fig. 7 — Hot Twist Ductility of Austenitic 18-10 Stainless Between 2000 and 2500° F.



tenite or a mixture of austenite and delta ferrite, depending upon the temperature and alloy composition.

A study of the diagrams does show a definite relationship between the microstructure and ductility as measured by the hot twist test. For example, Fig. 7 shows that the ductility of the 18.4% chromium, 10.5% nickel alloy, which is austenitic at all temperatures, increases at a uniform rate as the temperature increases from 2000 to 2400° F. (1095 to 1315° C.). Microstructure of this alloy, after rapidly quenching from 2000, 2200, and 2400° F., is completely austenitic; the only structural change that was noted is a

Fig. 8 — Ductility and Corresponding Microstructure of Properly Balanced 18-12-Mo Stainless

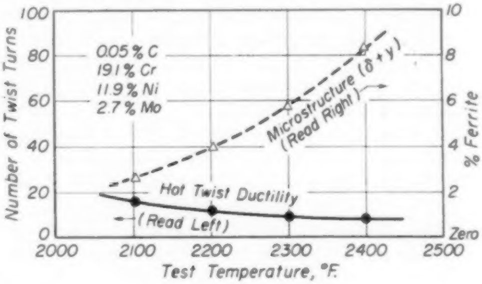


considerable increase in grain size with increasing temperature.

The 18-12-Mo alloy diagrammed in Fig. 8, which contains 18.1% chromium, 11.5% nickel, and 2.8% molybdenum, exhibits an entirely different type of temperature-ductility curve. With increasing temperature the ductility increases gradually from a minimum at 2000° F. to a maximum at around 2300° F., and then gradually decreases as the temperature is raised to 2450° F. The loss of ductility of this alloy at higher temperatures is clearly related to the formation of a two-phase structure — namely, austenite plus ferrite. Micrographic studies show that this alloy is 100% austenitic after quenching from 2100 and 2300° F., and that small islands of delta appear both within the grains and along the grain boundaries after quenching from 2400° F.

The effect of molybdenum additions in promoting the formation of the delta phase in 18-8 stainless has been known for quite some time; it is also well known that, when present, this phase is harmful to the hot working character-

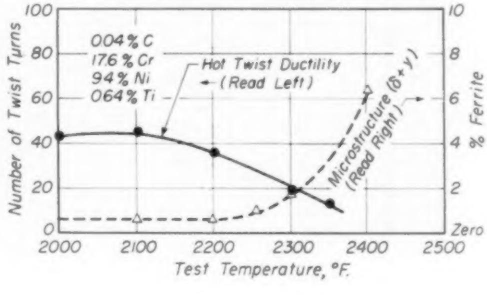
Fig. 9 — Deficient Hot Twist Ductility in Two-Phase Structure of Improperly Balanced 19-12-Mo Stainless



istics. Propensity for formation of this phase can be suppressed by keeping the ferrite-promoting elements (such as chromium and silicon) as low as possible, and the austenite-promoting elements (such as carbon, manganese and nickel) as high as possible. Considerable industrial effort has been devoted to the problem of establishing the proper quantities or "balance" of elements — bearing in mind, of course, their effect not only on hot working characteristics, but also on the mechanical properties and the resistance to corrosion in various media.

Newell and Fleischmann,[5] for example, pro-

Fig. 10 — Hot Twist Ductility of 18-10-Ti



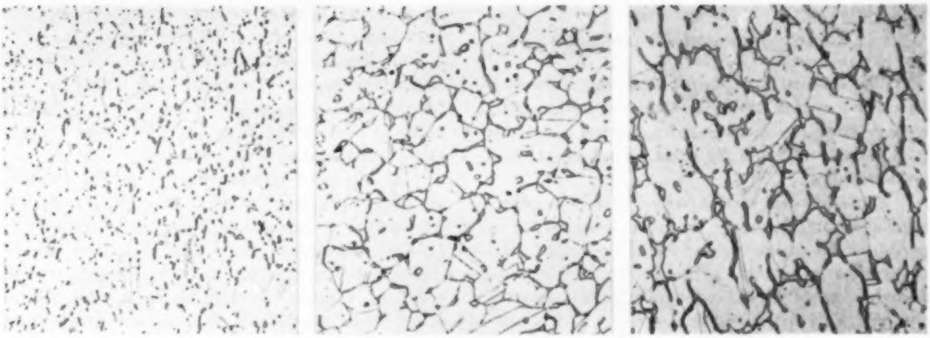


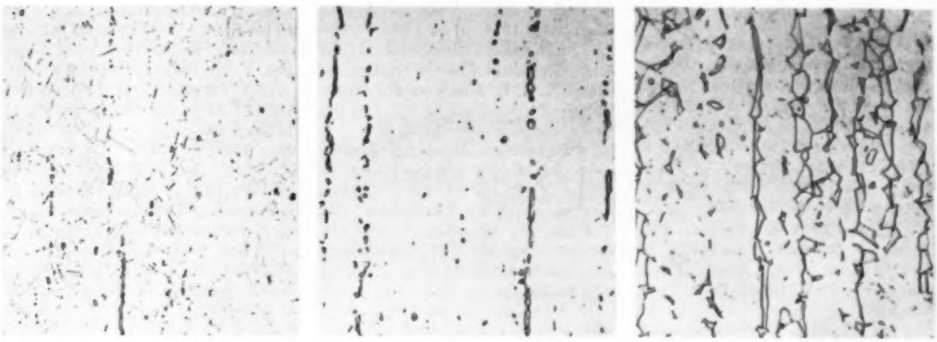
Fig. 11 — Microstructure of 19.1% Chromium, 11.9% Nickel, 2.7% Molybdenum Stainless Steel After Brine Quenching Specimens From 2100, 2300, and 2400° F. Etchant, mixed acids in glycerin; magnification, 200×

posed a method of balancing the composition of molybdenum-bearing stainless steels to secure satisfactory results for the hot piercing of seamless tubes. The American Iron and Steel Institute's chemical composition limits for standard stainless steels recognize the desirability for composition balance in regard to hot workability by permitting higher manganese and particularly higher nickel contents in the chromium-nickel alloys containing the ferrite-promoting elements such as molybdenum, silicon, titanium and columbium.

The unfavorable effect of a two-phase structure is markedly evident in the highly unbalanced alloy containing 19.1% chromium, 11.9% nickel, with 2.7% molybdenum (Fig. 9). This material shows a steady decrease in ductility throughout the range 2000 to 2400° F. Figure 11 depicts the structure (austenite plus delta ferrite) of this alloy after quenching samples from 2100, 2300, and 2400° F. (1150, 1260, and 1315° C.).

The alloy containing 17.6% chromium, 9.4% nickel, and 0.64% titanium (Fig. 10) has been included as further evidence of the relationship between structural change and hot ductility of the austenitic alloys. Because of the titanium in this alloy, it contains a small amount of delta ferrite even as low as 2000° F. (Fig. 10 and 12). At 2200° F. the amount of this phase begins to increase rapidly and the twist values fall off correspondingly. Speranski,[8] who made an extensive study of the hot piercing characteristics of chromium-nickel stainless steels with various quantities of titanium, recommended that the chromium and nickel be carefully balanced and the titanium and silicon contents be held below certain definite limits to restrict the formation of delta ferrite.

Fig. 12 — Microstructure of 17.6% Chromium, 9.4% Nickel, 0.64% Titanium Stainless Steel After Brine Quenching Specimens From 2000, 2200, and 2400° F. Etchant, mixed acids in glycerin; magnification, 200×



Conclusions and Discussion

The ductility of plain chromium as well as chromium-nickel stainless steels at hot working temperatures, as measured by the hot twist test, is markedly affected by their structure at these temperatures.

Austenite and ferrite, when present together, appear to cause poorer ductility than when the predominant phase for a given alloy composition is present by itself. Thus, when the critical temperature of an alloy is passed, the ductility changes sharply, becoming poorer if it passes into a two-phase region and superior if into a single-phase region.

In the plain chromium stainless steels, ferrite appears to be more ductile at a given temperature than austenite.

In chromium-nickel steels the appearance of delta ferrite in the structure is harmful to hot ductility. This effect may be conquered or substantially suppressed by suitable balance between ferrite and austenite-promoting elements in the steel's chemistry.

Comparing the hot twist ductility of 18-10 and 18-12-Mo at temperatures up to 2300° F., wherein both alloys are completely austenitic (Fig. 7 and 8), the curve for number of twist turns is considerably lower for the molybdenum-bearing alloy. This is to be expected, since molybdenum is a strengthening element and hot ductility is usually inversely proportional to the strength or hardness; likewise, molybdenum is quite useful in a wide variety of steels to increase creep strength at high temperature. Note, however, that this disparity in hot ductility is much greater when the second phase appears in the 18-12-Mo.

The apparently anomalous effect of extremely high hot ductility (number of turns in twist test) in a purely ferritic structure, such as the 26% chromium alloy has at 2450° F. (Fig. 3), while a small amount of the same phase — presumably still quite ductile — embedded in a ductile austenitic matrix results in a much lower number of turns in a twist test (Fig. 1), is puzzling. A tentative explanation is as follows:

At elevated temperatures, purely ferritic structures are much weaker than purely austenitic alloys. Thus, at temperatures above 1000 to 1200° F., austenitic materials are used almost exclusively in applications where high tensile, creep or rupture strength is required. Where other structural effects such as the presence of precipitates do not enter the picture, ductility will normally vary inversely in proportion to strength. It seems likely that purely ferritic structures will be much softer and, conversely, more ductile at corresponding high temperatures than purely austenitic structures. It is, no doubt, for this reason that at 2300° F. the wholly ferritic structure of Type 446 (26% Cr) exhibits much more ductility than the wholly austenitic structure of 18-10. The factor which markedly alters this relationship is the pronounced effect which transformation, resulting in two-phase structures, has on ductility. It was this effect which we bring out in this paper.

In the temperature range where ferrite and austenite coexist in 26% chromium alloys we found a distinct drop in ductility. (See Fig. 3.) Similarly, as soon as ferrite begins to appear in austenitic alloys such as 18Cr-12Ni-3Mo we also found a definite loss in ductility, as shown in Fig. 8. Just why a small amount of austenite in a ferritic alloy (or, conversely, a small amount of ferrite in an austenitic alloy) has such an effect on hot ductility has not been explained. It is generally true, however, in most metals that two-phase structures are not as ductile as the pure phases themselves.

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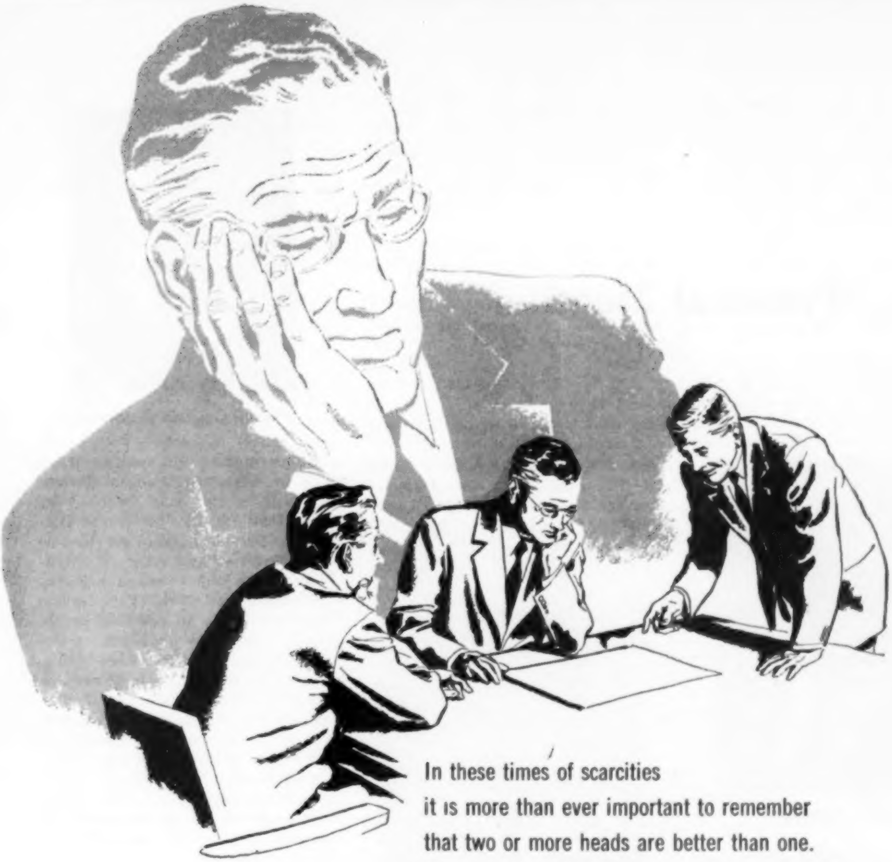
[5]"Hot Rolled Metal Articles and Method of Making Same", H. D. Newell and Martin Fleischmann, U. S. Patent 2,118,683 (1938).

[6]"Hot Working Properties of Stainless Chromium-Nickel Steels With Additions of Titanium", V. Speranski, *Stal*, V. 9, No. 4-5, 1939, p. 28 to 35.



Personal Mention

Hyman Bornstein

C. D. Wiman, president of Deere & Co., a leading producer of farm machinery, has announced that **Hyman Bornstein** ⊕, since 1920 director of Deere's research laboratories and materials engineering department, would become Chief Technical Consultant, "to deal with problems in terms of tomorrow rather than the urgencies of today". Hy Bornstein is most widely known for his work in the field of high-grade cast iron, as well as in the development of high-strength, wear resistant and alloy cast irons. The past 30 years has been the period when power farming has become widespread, with steady improvements in tractors and implements. Despite the duties of his position he has headed the technical committees on cast iron of the American Foundrymen's Society (of which he was one-time president), and the American Society for Testing Materials. He has been active in the Moline Chapter ⊕ since its organization, and has served as Trustee of the National Society. In 1946 he received the McFadden Gold Medal of the American Foundrymen's Society, and in 1948 the ⊕'s Distinguished Service Award for meritorious contributions to progress in alloy steels.

Francis T. McGuire

Succeeding H. Bornstein as manager of materials engineering department of Deere & Co., Moline, Ill., is **Francis T. McGuire** ⊕. McGuire received his advanced degree in metallurgy from Notre Dame in 1941 and for the next two years taught at the University of Kentucky — at the same time supervising a governmental research into the properties of alloy steels at low temperature. From 1943 to 1945 he directed the laboratory of Republic Steel Co.'s plant in South Chicago, then rapidly expanding into an electric furnace producer of gun steel ingots. From 1945 to 1949 he was foundry manager of Sibley Machine & Foundry Co., South Bend, Ind., leaving there a year ago to join Deere & Co.'s research laboratories.

Hiland Garfield Batcheller

The highest distinction which can be bestowed upon a civilian for war service was awarded by President Truman to Hiland Batcheller for his notable services as vice-chairman and chief of operations of the War Production Board from 1943 until 1945. This service was carried on in addition to his regular duties as president of the Allegheny Ludlum Steel Corp. while the company was rapidly expanding its production of war materials and conducting research necessary to the war effort. A few years later, Hiland Batcheller, an internationally known industrialist and advisor in world affairs, was awarded the ⊕ Distinguished Service Award "for supporting a lengthy program of development of electrical sheets of improved magnetic properties". Since the war, Mr. Batcheller has been a member of the President's Non-Partisan Committee on European Aid.

Hiland Batcheller was born in Brooklyn in 1885. He entered the sales department of Carnegie Steel Co. in 1909, shortly after graduation from Wesleyan University, Middletown, Conn. He left in 1915 to become assistant to the president of Ludlum Steel Co., was promoted to vice-president in 1918, and to president in 1930. Following the merger of Ludlum Steel Co. with Allegheny Steel Co. in 1938, he became president of the new Allegheny Ludlum Steel Corp., and recently has become chairman of its board of directors.

The great scope of Hiland Batcheller's activities can be visualized by the number of organizations upon whose directorates he serves. These include the Arnold Engineering Co., the Wallingford Steel Co., and the American Iron

and Steel Institute; he is a trustee of the Committee for Economic Development, Rennsselaer Polytechnic Institute, and his alma mater, Wesleyan University.

P. E. Page, has been transferred by the Navy from duties as inspection administration officer at the Office of Supervising Inspector of Naval Material, Pittsburgh, to have charge of inspection of naval material at Buffalo.

Charles R. Baker, has accepted a position as chief metallurgist for the Owens-Illinois Glass Co., Toledo, Ohio, in the general research and new development department.

W. F. Chubb, has taken over the Foundation Chair of Metallurgy at King Fouad 1st University, Giza, Cairo, Egypt, and will act as consulting metallurgist to the Ministry of War and Marine.

Bausch & Lomb Optical Co., Rochester, N. Y., announces that **Howard S. Coleman**, formerly head of the optical research laboratories at the University of Texas, has become director of the company's Scientific Bureau.

John H. Gambill, Jr., is now working as research technologist at the research laboratory of the U. S. Steel Co., Pittsburgh.

Zay Jeffries, former vice-president of the General Electric Co., has recently been elected to the board of directors of the Cleveland Electric Illuminating Co.

Garry C. Neur, is now organizing the Battle Creek Metal Products Co. and is tooling the shop to fabricate metal equipment for the Atomic Energy Program.

David W. McDowell, Jr., has been recalled to active duty with the Naval Reserve and is acting as assistant to the terminal ballistics officer at the U. S. Naval Proving Grounds, Dahlgren, Va. He was formerly associated with Titanium Alloys Manufacturing Co., Niagara Falls, N. Y., and the University of Buffalo.

T. N. DeVries recently took a position in the ferrous metallurgical department of Chrysler Engineering in Highland Park, Mich.

Eugene S. Machlin, has completed requirements for his Sc.D. degree and joined the staff at Massachusetts Institute of Technology as an assistant professor in the dement of metallurgy.

After having completed graduate work at Carnegie Institute of Technology, **Arthur J. Opinsky** accepted a position as experimental metallurgist in the metallurgy department of the Research Laboratories Div. of General Motors, Detroit, Mich.

Since his graduation from the University of Michigan, **Robert C. Behnke**, has been metallurgist with the Muskegon Motor Specialties Co., Jackson, Mich.

Thomas M. Logan, has been recalled to active duty as commanding officer of the 403rd Engineer Base Depot, Ft. Leonard Wood, Mo.

Ernest G. Kendall, is now process metallurgist at the Titanium Div. of the National Lead Co., Boulder City, Nev.

Bert R. Lanker, is now employed by the Bingham-Herbrand Corp. as chief metallurgist to establish a chemical and metallurgical laboratory at the Herbrand Div., Fremont, Ohio.

Personals

William G. Weber, is employed as an assistant physical testing engineer with the Materials and Research Dept., Division of Highways of the State of California.

Arthur A. Coward, Jr., has recently been named relief supervisor in the metallurgical department of the National Tube Co., Lorain Works, Lorain, Ohio.

Robert D. Kesler, left Battelle Memorial Institute in October 1950 where he was employed as research engineer to accept employment with Kaiser Steel Corp., Fontana, Calif., as industrial engineer.

L. P. Bokanyi, formerly tool design manager at the wheel and brake division of Goodyear Aircraft, and recently owner of a manufacturers representative firm in Cuyahoga Falls, Ohio, is now a district representative of the Baker Industrial Truck Div. of Baker-Raulang Co., Cleveland, Ohio.

A. R. MacVittie, has been promoted from senior technical assistant to assistant to the superintendent, Electro Metallurgical Div., Union Carbide & Carbon Corp., Alloy W. Va. Works.

William A. Vensel, who, until early in 1950 owned and managed the Southworth Co. in Los Angeles, Calif., is now operating the Wm. A. Vensel Co. at 1423 So. Broadway, Los Angeles, Calif.

Bernard Anscher, formerly chief of fabrication and metallurgical development at the Atomic Energy Commission's New York operations office, has joined Hydropress, Inc., New York, N. Y., as engineer on special projects and sale of hydraulic metalworking machinery.

W. W. Rueckert, has returned to the design of presses and other heavy machinery with the E. W. Bliss Co., Canton, Ohio, a company for which he worked previous to 1931.

Art H. Allen, has transferred back to Cleveland as associate editor on special editorial projects for Penton publications, from the Detroit office where he was editor of *Steel* and other publications.

H. Raymond McCoy, chief metallurgist of Ohio Steel Foundries, Lima, Ohio, for the past 10 years, has returned to American Steel Foundries with whom he was associated for 25 years in various capacities. His new position will be at their new cast armor plant in East Chicago, Ill.

Morris E. Nicholson, has left Standard Oil Co. (Ind.) to join the Institute for the Study of Metals at the University of Chicago, as a research associate.

James V. Leninger, formerly in the general sales office of the Babcock & Wilcox Tube Co., is now employed in the Cincinnati office of Miller & Co. of Chicago as service and sales engineer.

William S. Morrison, Jr., has accepted a teaching fellowship at the South Dakota School of Mines and Technology from which he graduated in June 1950, and is doing graduate work toward an M.S. degree.

Formerly with the Chas. C. Kawin Co., Chicago, **Elmer J. Carmody**, is now manager of Engineering Foundry, Inc. He is also functioning as technical advisor.

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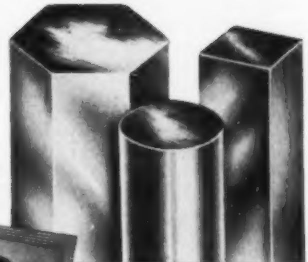
JALCASE 10

J&L STEEL



Maybe you haven't gotten the word yet, but more and more machinists are "discovering" Jalcase 10 (A.I.S.I. No. C-1144), the top grade of J&L Cold-finished Jalcase. And they're getting good results, too! Here's why.

Jalcase 10 is the highest carbon grade of Jalcase; it has high mechanical and machinability properties. This makes Jalcase 10 ideal for those tough "in between" machining applications. For instance:

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Personals

Precision Scientific Co., Chicago, Ill., announces that **Erwin Steffens**, recently joined the company as head of the metallurgical department. Formerly he was associated with R. W. Hunt Co. where he was metallurgist in executive charge of engineering work.

Herbert Lipson, formerly employed with Sylvania Electric Products Inc., is now employed as a physicist with the Brookhaven Physics Department.

The Midvale Co. of Philadelphia announces the appointment of **John A. Petroskas**, as chief metallurgist. He was formerly a staff metallurgist at Electric Storage Battery Co.

Harold B. Wishart, was recently appointed chief metallurgist at the Gary Steel Works, Carnegie-Illinois Steel Corp., Chicago, Ill.

Francis C. Frary, director of Alcoa Aluminum Co.'s aluminum research laboratories, was honored by the University of Minnesota recently when the school presented him its Outstanding Medal of Achievement.

Richard A. Schaus, has been moved to San Francisco as metallurgical engineer for alloy, stainless and tubular products for Columbia Steel. He was formerly senior service metallurgist for the Southern Div.

Gilbert Packer, formerly abrasives engineer with the Coated Abrasives Div. of Armour & Co., is now production engineer with Davis & Geck, Inc., Brooklyn, N. Y.

Norman F. Tisdale, chief engineer of the Molybdenum Corp., Pittsburgh, Pa., was recently appointed chairman of the newly formed advisory council for engineering in the Faculty of Applied Science at Queen's University, Kingston, Ontario.

John F. Tyrrell, formerly research metallurgist, Solar Aircraft Co., has joined the business staff of the American Society for Metals. Mr. Tyrrell will be located in the Society's New York office.

Howard B. Johnson, is now working as sales engineer for the Atlas Steel Casting Co., Buffalo, N. Y. in the New York, New Jersey and New England areas.

White Rust on Zinc*

THREE important losses due to "white rusting" of galvanized parts (formation of basic zinc carbonate) were investigated by the British Nonferrous Metals Research Assoc. in recent years, and Messrs. Gilbert and Hadden attempted to fix the causes and contributory factors in a series of well-planned experiments on commercial zinc coatings and on electrolytic zinc sheet.

Stagnant liquid water (usually condensate from humid atmospheres) is a necessity for white rusting. Interiors of stacks of sheet or of tight coils of wire are therefore only slightly tarnished even though the exteriors are badly corroded. Of the various contaminants in industrial atmospheres, SO_2 and HCl accelerate the corrosion materially. Acid vapors given off from electrical insulation tapes are also accelerators.

As to conditions associated with the metal itself, surface roughness has little effect. The natural zinc oxide film is a considerable protection; the first-formed film is as efficient as the thicker one on aged articles. Electroplated articles rust more copiously than hot-dipped, possibly because the latter have a more impervious oxide film.

Composition of the commercial coatings is responsible for the following variations in weight loss by white rusting in identical test conditions: Pure zinc: 0.017 oz. per sq.ft.; same with 1.2% lead added: 0.021 oz. per sq.ft.; commercial zinc with no lead added: 0.023 oz. per sq.ft.; same with 0.05% aluminum added: 0.007 oz. per sq.ft. The above are for well-cleaned coatings; residues of flux are bad accelerators.

It is known that strongly acidified sodium dichromate solution will protect zinc as well as aluminum and magnesium. However, the treatment is rather expensive. The investigators found that if the hot-dipped articles were immediately quenched for at least 30 sec. in unacidified 0.07% dichromate solution with no wetting agent (the solution being at room temperature), a surface film was created that was four times as effective as the one remaining if the galvanized article were quenched in cold water — the criterion being weight loss under the standardized test (Cont. on p. 266)

*Abstract of "White Rust Formation on Zinc", by P. T. Gilbert and S. E. Hadden, *Journal* of the Institute of Metals, September 1950, p. 47 (Paper No. 1269).

White Rust on Zinc

(Continued from p. 264) conditions for producing white rust. Carryover of flux does not harm this quenching solution. If the slight yellowish stain caused by the dilute dichromate is objectionable, it can be prevented by immediate rinsing, with no damage to the protective action. Care must also be taken to prevent mechanical damage to the chromate films (particularly before they are dry) and they should not be heated above about 70° C. if optimum protection is to be obtained.

The authors' words on storage of galvanized articles may be quoted.

"The conditions which will lead to condensation of appreciable amounts of water on zinc surfaces involve *(a)* a humid atmosphere, and *(b)* cooling of the metal surface below the temperature of the surrounding air. For instance, if a large mass of metal is stored in an unheated building, the temperature of the metal can fall considerably during the night. If, next morning, warm air of high humidity comes into contact with the metal, much condensation will occur. This is observed when on misty or foggy mornings condensation appears on metal stored in buildings partly open to the outside atmosphere. If metal is stored in a room which is not affected by outside humidity changes, there is much less chance of condensation on the metal. If a room containing warm air is cooled by conduction through the walls there is likely to be much more condensation on the walls than on the metal inside the room. In such circumstances it is, however, possible for condensed water to run from the ceiling or the walls onto the stored metal, and so produce white rust."

Heat Treatment in Wartime Germany*

IN the treatment of forgings, considerable emphasis was placed on thorough annealing. For all larger forgings, carbon or alloy, the ingots were brought *(To p. 268)*

*Abstract from "The Ferrous Metal Industry in Germany During the Period 1939-1945", by George Patchin and Ernest Brewin, Over-all Report No. 15 of the British Intelligence Objectives Subcommittee, obtainable from British Information Services, 30 Rockefeller Plaza, New York City 20. ($1.15.)

Another of the Jobs* that Stainless Steel does BEST

*Fire Extinguishers

that are LIGHTER

STRONGER

LONGER LASTING

HERE'S an old friend with a handsome new face—and definitely new sales appeal, too! Can you improve a fire extinguisher, without materially changing the design or method of operation? The answer is emphatically *yes*—by making it of stainless steel.

For one thing, fire extinguishers made of Allegheny Metal are a third *lighter* than ordinary types. Women can operate them easily, and that could mean many a fire brought under quicker control, causing less damage. A second point: stainless extinguishers are at least 50% *stronger.* They're tested to much higher hydrostatic pressure than older types—which means they're potentially safer, longer-lasting, and better able to take a beating. And third: they're *better-looking*—always bright, smart and efficient in appearance—a strong sales point with any buyer.

So—add fire extinguishers to the thousands of uses today for stainless steel. How about you? What jobs do you have where Allegheny Metal will pay you a profit? *Let us help you to find out.*

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Complete technical and fabricating data—engineering help, too—are yours for the asking from Allegheny Ludlum Steel Corporation, Pittsburgh, Pa. . . . the nation's leading producer of stainless steel in all forms. Branch Offices are located in principal cities, coast to coast, and Warehouse Stocks of Allegheny Stainless Steel are carried by all Joseph T. Ryerson & Son, Inc. plants.

You can make it **BETTER** with

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AL TIME-TESTED STAINLESS STEEL

Heat Treatment in Wartime Germany

(Cont. from p. 266) hot to the forging furnaces for reheating and were forged before cooling down. In the case of steels with a tendency to flaking, great care was taken to avoid this by slow cooling, either in pits or furnaces or by covering with local gravel. No great study, however, appears to have been made to find the most economical method of cooling to eliminate flakes. Smaller forgings were covered in sand and cooling might take anything from 4 days to 5 weeks. Larger forgings were soaked at 1200° F., heated to 1650° F., soaked, cooled in the furnace or air to 1200° F., held at this temperature for a time dependent on the load, and then cooled in the furnace to below 200° F., the time being anything from 10 days to 5 weeks.

The final treatment of forgings showed no departure from normal. Practically no electric furnaces were used for treatment, gas firing being mainly used. Emphasis was laid, however, on adequate heat capacity in the furnaces.

At Bochum, centrifugally cast gun tubes were first pit cooled slowly over a period of about 8 days from above 1800 to 400° F., after which they were subjected to a diffusion anneal at 1830 to 2000° F. for 6 to 18 hr. The time taken depended on composition and wall thickness. After this they were normalized and annealed for best machinability. Final treatment consisted of heating to 1650° F. and cooling to 1580° F. in the furnace, quenching in oil to 300° F., tempering at 1150° F. to obtain the tensile strength required, followed by a quench in water to obviate temper brittleness.

Cast armor was first normalized at 1650° F. Up to February 1944, all German cast armor was subsequently oil quenched, usually twice for the largest sections. The second hardening temperature was some 50° F. below the first. After the above date, water quenching was permitted if the shape and dimensions of the casting were such that it did not cause cracks to appear. The water temperature had to be over 140° F. All castings were oil or water quenched from the tempering temperature to obviate temper brittleness. A sorbitic structure with "no free ferrite" was aimed for in regard to the heat treatment of cast armor. *(Continued on p. 270)*

Heat Treatment in Wartime Germany

(Starts on p. 266)

With the exception of very light armor, 5 to 14.5 mm. (0.2 to 0.57 in.) heat treatment of German homogeneous rolled armor consisted of a conventional hardening and tempering treatment. Homogeneous light armor in the thickness range 0.2 to 0.57 in. was considered by the Germans to be in a special category. Comparison with other thickness ranges showed that, in general, more alloy had been used for this thin plate than for the next two heavier ranges. This special consideration resulted apparently from an attempt to obtain high immunity to rifle and machine gun projectiles, while still maintaining sufficient toughness to withstand the shock of high explosive without shattering. The type of steel used contained 0.38 to 0.48% C, 1.30 to 1.65% Si, 0.80 to 1.10% Mn, 0.95 to 1.25% Cr, and was always oil quenched.

Krupp's, one of the chief producers of armor plate, had not altered its methods from those prior to the war, except for the introduction of gas carburizing instead of the usual pack carburizing. According to one authority, plates treated by the gas carburizing process ranged from 100 to 400 mm. (3.9 to 15.6 in.). A battery of specially-constructed movable-hearth-type furnaces was used, heated by coke oven gas burnt through side burners. Carburizing under typical conditions required 11 days at 1800 to 2000° F.

Plates for flame hardening were of compositions similar to those used for homogeneous armor. The carbon content ranged from 0.32 to 0.45%, and the plates received the same preliminary heat treatment as the homogeneous plates. The desired depth of hardened face for 1.2-in. thick armor was 0.098 to 0.155 in., while for 2-in. thick plates a case depth of 0.118 to 0.197 in. was the objective. The surface hardness aimed for was 600 Vickers. The flame hardening process apparently gained impetus during the war years; either acetylene or town gas was used as fuel.

In addition to plates, such parts as machine gun mantlets and ball mountings were also flame hardened. Ball mountings were heated while being rotated under a profiled burner flame. The ball was quenched, while still rotating, by water jets from a hood which was moved over it. *(Continued on p. 272)*

Heat Treatment in Wartime Germany

(*Starts on p. 266*)

There appear to have been two distinct installations in Germany which produced face hardened armor plate by electrical induction—one at Dortmund-Horde and the other at Hannover belonging to D.E.W. The Dortmund installation was primarily used for thick plate and could operate at either 50 or 500 cycles, the power required being 4500 kva. or about the same as that required for a 6-ton electric furnace. A penetration of 3 in. was obtained over a width of about 7½ ft., at a speed of 9 in. per min.

In the Hannover plant, the coil enclosed a rectangular space through which the plate passed at a uniform speed depending on the plate thickness (2 in. thick, 12 in. per min.). The upper conductor was hollow and water cooled. It was surrounded by iron laminations of special design, the whole being mounted in bakelite. Water jets from the conductor mounting quenched the plate after heating. The lower conductor was of much larger section and produced a very weak field. After hardening, plates were heated to between 300 and 350° F. before passing through final straightening rolls.

Inquiries were made concerning the use of the "martempering" process for bearing components. The process called *Warmhartung* (hot hardening), which had been used for rings with satisfactory results, was considered to be the German equivalent of martempering. The treatment reported at Kugelfischer, and quoted as an example, was not strictly martempering, but a quench into a warm bath (about 400° F.) to reduce danger of hardening cracks.

Quenching Directly From Rolling—Experiments on quenching bars and billets directly from rolling were made at Ruhrstahl. In the first experiment, bars directly after rolling were made to enter a tube flushed with water. One of the principal drawbacks was that the bars came out of the cooling tube twisted. The form of the plant was accordingly modified by using a cooling tube of very small diameter, this change producing favorable results when applied to bars up to, say, 1 in. diameter.

After the completely cooled bar had been removed from the cooling tube, it was cut to the required lengths by an abrasive disk saw and tempered. To minimize the danger

of cracking and the slowing of production involved in cutting. Ruhrstahl considered the possibility of tempering the entire length of the rolled bar by electrical means.

Experiments on quenching bars direct from rolling had also been made by Gebrüder Böhler. The method developed differed from that used at Ruhrstahl, the rolled bars being rushed into the quenching bath and transferred after cooling to a roller conveyer, by which they were brought to the annealing furnace. Although no delay took place in mill production, more work had to be spent on straightening.

The following, quoted from an interrogation report, should be of interest: "Hardening directly from rolling heat is basically new; its results are good because the steel is held for a long time before rolling, so that all the carbon is always dissolved. This is not changed by rolling."

The hardening of steels from rolling heat has been investigated by P. Drastik and has been compared with the results obtained by normal heat treatment methods. The comparison showed that: *(a)* The variation in physical properties is less pronounced than in normal heat treatment and *(b)* the test results, particularly notch-impact strength, elongation and reduction in area for equal tensile strength were considerably higher than with normal heat treatment. T. L.

Corrosion of Marine Condenser Systems

EXCESSIVE corrosion of ships' condenser tubes came under intensive study 40 years ago, and it was found that the trouble depended to a remarkable extent upon the working conditions. Nevertheless, knowledge of the older and some new alloys and of design improved so one or another alloy can be safely used. Marked recent increase in severity of operating conditions in naval vessels caused trouble in other parts of the main cooling system where attack had not been expected. The present paper* is a brief summary of a reference guide for ships' officers, repair authorities, and designers for identifying the types of *(Cont. on p. 274)*

*"Corrosion and Related Problems in Sea Water Cooling and Pipe Systems in the H. M. Ships", by I. G. Slater, L. Kenworthy and R. May; *Journal* of the Institute of Metals, Vol. 77, 1950, p. 309. Paper 1253.

Corrosion of Marine Condenser Systems

(*Starts on p. 273*) corrosion and the factors responsible, and putting into effect such methods to overcome or minimize the troubles as at that time could be recommended.

The authors record their appreciation to the Engineer Officers of the Royal Navy, "who, in the stress of war, inspired and made possible much of the work, not only by affording facilities to see, discuss, philosophize, and experiment, but also by having faith in the scientists' prognostications".

The three most prominent types of corrosion deterioration are impingement attack, pitting, and attack under foreign deposits. A rough guide to the relative resistance of various materials is given in the table. The second column gives the average water speed in ft. per sec. at which risk of impingement attack generally arises in service. Resistance to pitting and to deposit attack in the third and fourth columns respectively is noted by the code M for moderate, G for good, VG for very good, and I for immune.

Approximate Corrosion Resistance

Material	Impingement	Pitting	Deposit
Copper	7	M	M
Admiralty / Naval brass	10	M	M
Cupro-nickel	15	G	G
Al brass	15	G to M	VG to M
Gun metal	20	VG	VG
Rubber	I	I	I

Excessive local turbulence, often caused by minor details in the design, is of great significance. "Moreover, seawater is far from being a homogeneous or uniform fluid and a ship's cooling system has to take all that comes its way, from air bubbles to the manifest unpredictables of marine muds, flora, and fauna, and all that sinks or floats therein. Juxtaposition of so many metals accounts for the significantly inferior performance of systems during the early history of many ships, as a result of galvanic attack and its effect in promoting other forms of corrosion. It is fortunate that seawater will deposit an insulating scale on the offending cathodic areas in due time and thus permit the formation of the natural protective film on the other metal sur-

(*Continued on p. 276*)

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ACCURATE TEMPERATURE CONTROL—Tolerances to ±2½° F.

UNIFORM HEATING—The unusual efficiency of the DESPATCH forced convection (cross flow) heat distribution system supplies heated air uniformly to every inch of the work chamber.

FAST, VERSATILE—High volume, high velocity fan transfers air heated to the desired temperature through the work chamber at tremendous velocity and under great pressure to bring work chamber up to required temperature in minimum time even with dense loads.

ECONOMICAL—Maximum efficiency from fuel is assured.

EASY TO USE—Smooth working doors, conveniently placed load shelves and handy controls eliminate unnecessary steps by operator. Saves time and labor.

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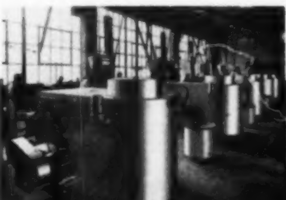
Available in either electric or gas models

No.	INSIDE DIMENSIONS, INCHES			Max. Temp.
	Width	Length	Height	
CF-10	13	13	13	850° F.
CF-18	19	19	19	850° F.
CF-26	37	19	25	850° F.
CF-32	37	25	37	850° F.
CF-9	13	13	13	1250° F.
CF-17	19	19	19	1250° F.
CF-25	37	19	25	1250° F.
CF-31	37	25	37	1250° F.

DESPATCH also engineers and manufactures a complete line of conveyorized and batch or pot type furnaces (to 1250° F.)



Battery of DT (Pot Type) Gas Fired Furnaces used to heat treat 20 mm. shell cases.

Battery of Despatch recirculating Furnaces for aging aluminum castings.

Write for New Bulletin No. 84P

DESPATCH
OVEN COMPANY

MINNEAPOLIS OFFICE:

CHICAGO OFFICE:

Corrosion of Marine Condenser Systems

(Starts on p. 273)

faces. Stagnant periods when marine muds activated by decomposing organic matter settle on the metal surfaces and destroy the natural protective films are yet another of the major problems."

Proper use of steel protectors can do much to limit attack of immediately adjacent nonferrous components, and provide iron corrosion products which become incorporated in the protective film on condenser tubes and other parts. Protection for a limited time can be secured by suitable paint coatings. Sheets of natural rubber "tailored" and bonded to the metal are proving very durable.

A better alloy for sheet and piping which has to be shaped and bent to form is a copper alloy containing small percentages of nickel and iron; this is now going into service for certain piping prone to impingement attack.

The majority of the available metals and alloys have their weak points and undergo some corrosion if the specific conditions to which the material is sensitive make their appearance. This tendency has to be considered along with the better properties of each. Of such properties, a natural protective film which only breaks down slowly even under the worst conditions and quickly forms again when these have passed is perhaps the most valuable and is more likely of attainment than complete resistance.

Advance Appraisal — At present, laboratory tests can simulate a number of the rarer and more damaging types of corrosive attack. "Information so gained would inspire little confidence, however, if tests were speeded up by introducing conditions never encountered in practice, or even by undue exaggeration of any of the known factors. The principle in use for a number of years is to take the maximum rate of attack observed in practice as a standard, and to arrange test conditions so that when using the same material this rate is approached, but not exceeded. It is also important that the essential factors introduced to obtain this rate of attack should be, so far as possible, the same as those which produce the same type of corrosion in practice, and furthermore, that none of them should be exaggerated much beyond what would occur *(Cont. on p. 278)*

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Technical Topics

RUST FORMATION ON 18-8 STAINLESS STEEL

Norman S. Mott
Chief Chemist and Metallurgist

The popular conception that rust can never form on 18-8 stainless steel, unless something is wrong with the chemical composition or the heat treatment, is a long way from the truth. Experience has shown that rust can occur on stainless alloys of controlled composition and heat treatment as the result of surface contamination. Among the many sources of contamination which may contribute to the formation of rust on the surface of stainless steels, the following are leading offenders:

1. An iron film left on the surface as the result of a machining or other manufacturing operation will tend to rust in the presence of moisture.

2. Microscopic scale particles left on the surface after pickling may become visible as "rust" under suitable conditions.

3. Pickling solution oozing from minute pores in the metal may stain the surface and oxidize to a brown rust color due to the iron which it contains.

4. The accumulation of the natural corrosion products of the alloy in corrosive service on a rough surface may cause a brown stain due to oxidation.

5. Discoloration may be caused by the accumulation of any extraneous processing material which is of such a nature as to cause a "rusty" appearance on a rough surface.

Articles that are to have a truly "stainless" appearance should have all scale completely removed by suitable cleaning methods, should be passivated after machining operations in warm dilute nitric acid, should be free from porosity, and should have a reasonably smooth surface.

A smooth or polished surface will always stay cleaner and brighter, and be more resistant under mildly corrosive conditions than a rough surface and this tendency increases with the degree of polish. Although it is true that stainless steel is at its best when highly polished, it should be remembered that under strongly corrosive conditions this polish is soon removed. For most applications, it is the inherent resistance of the alloy that counts and "rust" conditions such as those described are relatively harmless. They are the results of surface contamination and in no way reflect the composition of the alloy or the effectiveness of the heat treatment.

Corrosion of Marine Condenser Systems

(Starts on p. 273) under the worst practical conditions. Fortunately, these limitations do not make the tests unduly slow." For example, under the worst conditions of practice, failures of 70:30 brass condenser tubes occur in three weeks and hence this rate may be duplicated in laboratory tests without going beyond "legitimate conditions".

Some types of corrosion, like dezincification, progress slowly; no attempt should be made to speed these up in laboratory tests. Usually it is sufficient to note the *initiation* of the corrosion and to estimate its rate by comparison with known check specimens tested at the same time.

Very useful is a jet impingement test, wherein seawater at 17 ft. per sec. with 3% by volume of entangled air gives a rate of attack which represents fairly closely the local maxima that can occur in a cooling system with an average water speed of about 12 ft. per sec., when there is a considerable amount of turbulence and a local concentration of air bubbles. The test is run continuously for 28 days. If the specimen and the check specimen are unattacked in the first seven days, the protective film is scratched. Consistent healing of the scratch indicates corrosion resistance of a high order, unless, of course, the check specimen also heals, in which case it must be concluded that something has gone wrong with the test.

The jet test also detects pitting corrosion due to contaminating substances in the water. The pits may develop very close to the jet, or may be distributed over the surface under small blisters or localized at the points of contact with the holder, or occur on the back of the specimens remote from the jet.

The "rotor test" is useful for studying combinations of metals. The samples, connected together as required, are all attached to an ebonite rotor immersed in a tank of seawater and rotated at a suitable speed.

Finally, operation of small models of the condenser system is an important link between laboratory tests and large-scale trials.

The authors of this valuable summary show commendable restraint in their references to literature. From literally hundreds of published documents they chose only four.

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Pure Metals*

IN METALS for electrical and magnetic purposes the effect of minor impurities is outstandingly important, as has been known for a long time by the manufacturers of copper wire. More recent refinements in metallurgical processes and in spectrographic analysis have brought some of the obscure anomalies to heel. Take, for example, the recrystallization of "pure" lead at room temperature after heavy cold working: Two lots of lead were secured, *A* with less than 0.002% total impurities and *B* with about 0.010% total of the same impurities. To each of these 0.005% nickel was added, both heavily cold rolled and tested after equal aging. Originally, lead *A* had tensile strength of 2180 psi.; after alloying and treatment it tested 2360 psi., an increase of 8%. Corresponding figures for lead *B* were 2300 psi. originally, 3040 psi. alloyed, cold rolled and aged, an increase of 32%. Thus, "the danger of unsuspected variables is so great that the effects of impurities can best be investigated with limited batches of a number of materials similarly prepared and carried through identical rolling, aging, and testing schedules as a group".

Work of Yensen, Zeigler and Cioffi has shown the enormous improvement in the permeability as the impurities in "pure" iron (notably C, S, O and N) are progressively reduced. For example, commercial Armco iron with 0.062% of the above impurities has a maximum permeability of 7000. After 3 hr. heating at 2700° F. these impurities are reduced to 0.013% and the permeability is increased to 30,000. Heating 15 hr. longer brings the C + S + O + N to 0.011%, yet the permeability jumps to 227,000!

Nitrogen, by this heat treatment, is reduced to about 0.0001%. If above 0.0010% it has a markedly deleterious effect since a nitride precipitates gradually, and the harm increases with time — an effect not generally recognized because of the slowness of the change, and because the effect may have been obscured by the action of other minor constituents.

Similar control of trace elements is necessary for the handling of "semiconductors" *(Cont. on p. 282)*

*Abstract of "Metallurgy Behind the Decimal Point", by Earle E. Schumacher, Institute of Metals Division Lecture (1950), *Transactions*, A.I.M.E., September 1950, p. 1097.

Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION **X-ite**

Rhyminiscent

As I pause from press of business to pen this idle rhyme,
I'm taking inventory, for it's inventory time.
But it's not the stock I'm checking, nor dollars lost or won,
That concern me in accounting when final statements done.
I am thinking of the "life" I've spent, the things I've done and said,
The things I cannot figure in the black or in the red.
I am thinking of the men I've met in plants throughout the land,
Who've given of their time to me, held out a friendly hand.
Who placed a certain confidence in statements that I made,
And staked their judgment on my claims and on the game I played.
I am thinking of the fellows who have gone out of their way
To help me put my stuff across . . . they do it every day.
I see friendships that are ripening, that have stood the test of years,
Have I kept faith with those who trusted, or am I in arrears?
What are dollars, few or many, to record commercial strife
When checked against the finer things along the path of life?
In intercourse with fellowmen, the give and take of trade,
The profit of enduring worth is not the dollar made.
I am humble as I contemplate how little I can say or do
To show that I appreciate what Men . . . one may be you . . .
Have done to aid me on my way.

RHYMINISCENT is run again for the third time in twenty years. Trying now, we can't find better words. It's been grand growing up with A.S.M. and now as we face together the biggest job in U. S. history, it is with keen appreciation of serving with the "regulars" in the metals, automotive, aviation and process industries.

SNAFUSIS

The Nation ARMS again—and the SNAFUSIS of Bureaucracy spreads once more upon us. We of industry will expend much time and energy milling with muddled meddlers as we matriculate in red tape. Fewer New Deal "Professors", this time, we are told, will guide us. Maybe, repeat maybe, the ACADEMICONSTIFUSION will be a few decibels lower.

Memories linger of labor politics tied to D.P.C. facilities, of Government and labor connivance to abort apprenticeship training, of the F.B.I. with its hands tied by "top" orders, and draft exemptions for labor organizers. We are hopeful that such maggotgagging procedures, *paid for in blood and taxes,* won't be repeated. All of us have learned something, including Bureaucrats. *HOW much remains to be seen.*

There are many able and sincere men in the National Production Authority fighting for just and rational procedures. *They* need and *deserve* industrial *support.*

New Nickel is "allocated" with increasing acumen, but old nickel (nickel scrap), *a major part of the National Nickel supply, runs wild.* Is this *(a)* intelligent? *(b)* moronic? *(c)* politics? *You name it!* To the small alloy casting industry, their employees, and their customers, it is *sabotage.*

PATRIOTS

Patriots pause to honor Johnson for discovering the Navy, Acheson for discovering Russia, Truman for discovering the Marines, and, the Marines, of course, for finding those "invisible" Chinese "volunteers". Is it too much to expect Intelligence, military or political, to reach clear out to Korea? (Maybe it got moth-balled with the Navy or soft-balled with the State Department!)

"SILVER" LINING

Well, anyway, we didn't let down the scrap dealers. They were almost out of war surplus before the Government blessed their traffic in nickel scrap and loused up alloy producers, their customers, and the quality and service expectancy of their product-serving basic industries.

IMMATURITY

America has long had a mass idealism, a National naiveté unequalled in history. This, strangely, has been superimposed upon, almost obscuring our deep heritage of common sense, residing at all levels of society—even including the parasitic. The public is undoubtedly thinking straighter than our leadership. Even the yokels have lost patience with the diplomats.

It is dawning slowly that all of us *share the immaturity of the human race,* which is morally and intellectually unready to participate in the Communion of nations—and dwell in Peace. That, it appears, is historically and currently obvious.

FUNCTIONAL PROMISE

Whatever our spiritual and philosophical limitations and our disallusionment with politics, history records that the *inventive genius of man and his increased productive capacity has been the motive power of human progress.*

The Engineering Sciences are the true sciences. They progress geometrically, whereas the social and political pseudo-sciences progress arithmetically. This nation was never stronger in its power of invention, development, and, above all, production.

In the interval between wars, our Armed Services have made major contributions in research and development for defense (and industry) which, when *weighed against all efforts of Government, are, perhaps, the greatest value that the taxpayer has received for his dollar.*

—H. H. H.

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THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

Pure Metals

(Cont. from p. 280) silicon and germanium (Group IV elements), used in point-contact rectifiers and transistors. These metals have poor conductivity because the outer electrons attached to their atoms are completely occupied by bonding the atom into its proper place in the crystalline lattice. If, now, an atom of phosphorus or another element in Group V, having one extra electron in its outer shell, is introduced into this lattice, there is a spare electron available for carrying electric current. Phosphorus is therefore called a donor and is responsible for "n-type conductivity" (n for a negative mobile carrier of electricity, the loose electron). If, however, boron with only three outer electrons is added as an impurity, its deficiency seems to create a mobile hole, the locus of a positive charge. Boron and other elements in Group III of the periodic sequence are therefore called an acceptor for silicon or germanium, because it accepts an electron from a lattice bond, and the resulting conductivity is called the p-type, because the mobile carriers act as though they were positively charged.

Consider now some germanium which has a little of both phosphorus and boron, one a donor, the other an acceptor. The net result on the resistivity is not proportional to their sum but corresponds more nearly to their difference. These facts are of use in producing metal of acceptable characteristics. Take metal containing 30 times as much boron as phosphorus; owing to segregation the metal in the top of the ingot has too high a resistivity. Another metal containing twice as much boron as phosphorus has metal of too high resistivity in the bottom. A balanced analysis (5 boron to 1 phosphorus) has acceptable resistivity, top to bottom.

The author concludes: "What constitutes a 'minor' amount of added element we now see to be a matter of degree. Five parts of silver in 100,000 of lead change the strength of the lead. The removal of 30 parts of sulphur and two parts of nitrogen from 1,000,000 parts of iron produces a seven-fold increase in permeability. One part of antimony in 100,000,000 of germanium doubles the conductivity. Perhaps some day we shall be privileged to study the properties of really pure metals. The first problem is to secure them."

Alloys of Al-Zn-Mg-Cu*

IT was during the first world war that Walter Rosenhain and his co-workers tried to find a cheaper and better substitute for the ordinary duralumin and quite naturally selected aluminum-zinc alloys for their experiments. Beginning with 25%, they lowered the zinc content and added magnesium, and some of their rolled and hardened alloys had a tensile strength of more than 100,000 psi., but the elongation was zero and the strength continuously decreased in storage. Besides, the alloys were highly vulnerable to corrosion — even by so common a medium as tap water.

Later on, these experiments — abandoned by the British, who instead invented the "Y alloy" — were taken up by the Germans, and alloys of the duralumin type containing 8% Zn, with and without tiny amounts of lithium, came into use. They had a tensile strength of 70,000 psi. and 13% elongation, against 60,000 and 23% for duralumin and were far less corrosion resistant than duralumin.

Aluminum-zinc-magnesium alloys containing no copper were extensively used in France as a cheaper and stronger variety of duralumin. Unfortunately, to be really stronger they had to carry 8% Zn and 3 to 4% Mg, at which composition they tended to develop sudden brittleness. Extruded rods would show a tensile strength of 70,000 and a yield strength of 55,000 psi. with 10% elongation, but the latter would frequently drop nearly to zero, while the tensile strength might go up to 90,000 psi. — still below what Rosenhain got in his "E alloys".

French metallurgists found that an addition of 1.5 to 3% Cu stabilizes the alloys and that an addition of 0.25% Cr does not hurt them either; small amounts of iron and silicon can be allowed too (about 0.25% each). A comparison between the copper-free alloy "A-Z G" (7.5% Zn, 2.5% Mg) and "A-Z Gu" containing, in addition, 1.5% Cu is the subject of the paper which is reviewed here.

Unfortunately, the original contains no tables and diagrams of the

(Continued on p. 286)

*Abstract from "Recent Researches on Aluminum-Zinc-Magnesium-Copper Alloys", by A. Saulnier and G. Gabane, *Revue de Métallurgie*, 1949, p. 13-23.

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Alloys of Al-Zn-Mg-Cu

(Continued from p. 284)

mechanical, physical and chemical characteristics of the two alloys as obtained after different heat treating procedures. The whole work was done by what might be called the "elegant" methods of dilatometry and X-ray analysis, which are important and should be used by all workers in the alloy field — but not exclusively.

The authors prepared their alloys in two 20-lb. heats cast into round billets 2.5 in. in diameter. Only the purest raw materials were used. Billets were extruded into rods 0.315 in. in diameter, and the samples cut from these rods.

The amount of dilatometric work was prodigious. Six different temperature levels were used for solution heat treatment and seven for precipitation hardening.

The authors believe that in the A-Z G alloy precipitation begins with the compound $Al_2Zn_3Mg_3$, and is later joined by $MgZn_2$, but in the A-Z Gu alloy it starts with $CuAl_2$, is joined by $Al_5Mg_2Cu_2$ and later by $MgZn_2$, after which the alloy develops a tendency to brittleness, so that the precipitation of the latter phase should be excluded by aging at 275° F. and not higher than 320° F.

All told, the alloy A-Z Gu must not be pushed too high in tensile strength, lest its elongation become too low. A tensile strength of 70,000 psi. seems to be the best compromise, and this is not too far from regular duralumin, which frequently shows 63,000 psi. with over 20% elongation.

The high values of the yield strength are questionable because it is customary in Europe to obtain this property from a diagram recorded by the testing machine throughout the whole plastic range, and therefore showing the elastic range only crudely. Accurate extensometers are very rarely used for that purpose.

Somewhat doubtful also is the figure of 25,000 psi. for the fatigue limit. The authors mention that the fatigue limit of duralumin is 20,000 psi., while according to investigators in Alcoa's laboratory it is only 18,000 psi.; some French authorities give it as 17,000 psi.

Protection of Refractory Metals*

FOUR metals melting above 4500° F. (columbium, tantalum, molybdenum and tungsten) possess extremely desirable mechanical characteristics at temperatures above 1800° F., and if they did not oxidize so rapidly the problem of materials for jet engines would have been solved before it arose. Bueckle tried to answer the question as to whether the surface of such metals could be protected by some noble metal or neutral oxide. The first means, of course, the use of platinum or rhodium; the second, silica, alumina, zirconia or thoria.

For reasons that are not clear, Bueckle did not use electrolytic processes of plating platinum or rhodium on any of the four metals, but he covered tungsten with a strip of platinum and hot rolled the two together, obtaining a clad layer that protected the base metal fully when exposed for 30 min. at 2300° F. in a furnace open on both ends. Tungsten diffused into platinum at a fairly rapid rate, but there was no perceptible diffusion in the opposite direction.

Covering a strip of tungsten with platinum chloride and reducing the chloride by heating in a vacuum also produced a protective coating but this was not uniform enough. A uniform thickness of 20 microns seems to be required for proper protection.

Melting alumina, or its mixtures with thoria, on the surface of a strip of tungsten heated to 4500° F. in a high vacuum produced no coating. Precipitation of oxides from the vapor phase at temperatures above 4900° F. produced a nonadherent coating.

Continuous improvement was obtained when the oxides were mixed with powdered columbium in such a manner that pure metal was on one side and pure oxides on the other side in a mold cavity. Pressed under 54,000 psi. and sintered in vacuum, such composite bodies were protected from scaling and the oxides did not strip off. How far such a process could be used in industry, and how much the mechanical characteristics of the metal would deteriorate due to the

(Continued on p. 290)

*Abstract from "Surface Protection of High-Melting Metals to Increase Their Resistance to Scaling at High Temperatures", by H. Bueckle, *Metallforschung*, Vol. 1, 1946, p. 81-86.

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BROWN INSTRUMENTS

Protection of Refractory Metals

(*Continued from p. 288*)
admixture of oxides remains a moot question.

Quite beyond expectation were the results of heating samples that were immersed momentarily in hydrochloric acid or in a solution of chloride. Instead of the higher, easily melting oxides of tungsten, some low, high-melting oxides formed on the surface of the sample and the process of oxidation slowed down greatly. Bueckle's diagram indicates that tungsten so treated rapidly reaches the maximum degree of surface oxidation and stays there, while the untreated sample continues to deteriorate. M. G. C.

Creep of Pure Zinc*

CREEP tests at constant stress were made, both on single crystals and polycrystalline specimens of high-purity zinc in the form of wires 1 mm. diameter. With single crystal specimens, two types of creep curves were recorded: *(a)* S-shape, of the type observed by Burghoff and Mathewson on brass and *(b)* shapes similar to those observed by Andrade (that is, with the usual features).

With the S-shape curves the specimen deformed with intense slip in a few isolated regions. Such curves are characteristic for crystals having high values of λ and x, the angles between the basal plane and wire axis, when tested at temperature higher than 120° C. and at slow strain rates. The S-shape curve is believed to be due to a predominant softening effect in which the increase in resolved shear stress (resulting from lattice rotation accompanying glide) more than counteracts work hardening.

Crystals with $x < 45°$, when tested at temperatures below 120° C., deformed homogeneously and the second type of creep curve was usually obtained. However, no third and final stage of accelerated flow was observed and no specimens broke.

Metallographic study of electropolished single crystal specimens under test showed that the slip bands became more prominent as flow progressed. (*Cont. on p. 294*)

*Abstract of "The Flow of Zinc Under Constant Stress", by A. H. Cottrell and V. Aytekin, *Journal* of the Institute of Metals, Vol. 77, July 1950, p. 389.

Creep of Pure Zinc

(Cont. from p. 290) There was no indication of crystal fragmentation or recrystallization; thus, flow occurred only by slip.

With polycrystalline specimens the ordinary form of the creep curve was obtained. Metallographic examination before and during testing at 108° C. showed that the mode of deformation varied with the strain rate. At fast rates, the flow was characterized mainly by the formation of slip bands and twin crystals. At slow rates, thick boundaries associated with sliding along grain boundaries were observed, and the formation of "cell" structure within the original grains, similar to that observed by Wilms and Wood on aluminum, was quite common. Hence, flow of the polycrystalline zinc involved at least four processes — slip, twinning, cell formation and displacement along grain boundaries.

The creep curves were analyzed in terms of the concepts of transient and steady-state components, introduced by Andrade. The $\sqrt[3]{t}$ law was accurately obeyed by the transient component, and the rate of steady flow varied exponentially with stress and the reciprocal of temperature.

Empirical formulas describing the relationships between stress, steady-state flow, and temperature have been appearing with increasing frequency in the literature, so the authors present a proposal for a unified theory including terms which predict certain dynamic and transient effects known to exist during the deformation process. It is suggested that two separate processes of thermal activation are necessary for thermal flow: *(a)* the energy barrier must be overcome; *(b)* the energy required for internal changes due to recovery. For a complete formal analysis, the activation energies for flow and for recovery must be considered to be equal in magnitude for any fixed strain-hardening coefficient. This activation energy must be reduced linearly by stress.

The results of numerous experiments appear to agree fairly closely with the proposed theory, and the theoretical and experimental evidence presented in this paper justifies the well-known assumption that steady-state flow *is* a result of a balance between strain hardening and thermal softening.

THOMAS G. DIGGES

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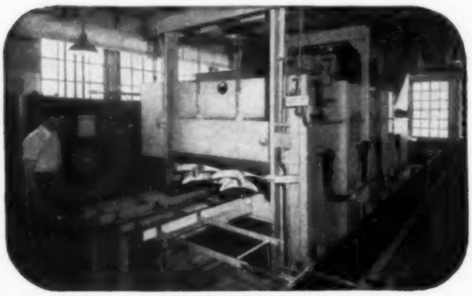

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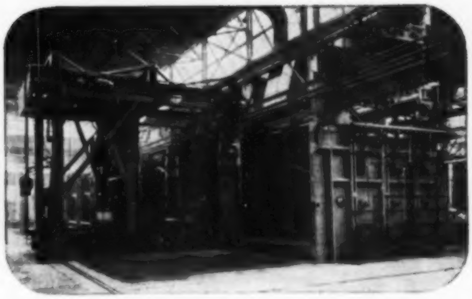

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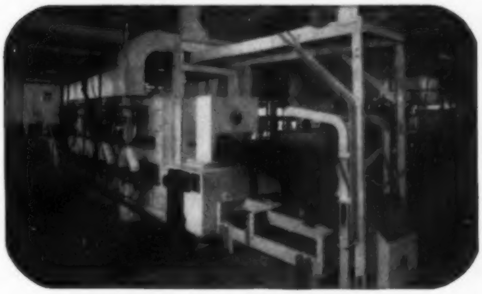

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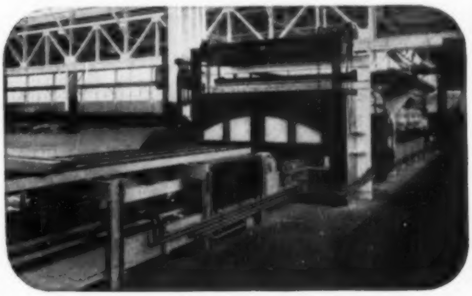

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